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THE UNIVERSTTY OF ALBERTA

PERIODICITY AND ECOLOGY OF THE PHYTOPLANKTON IN TWO ALBERTA LAKES

by

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The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies for acceptance, a thesis entitled PERIODICITY AND ECOLOGY OF THE PHYTOPLANKTON IN TWO ALBERTA LAKES, submitted by Eugene George Bozniak in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

A one year investigation of two lakes in central Alberta has provided a quantitative and qualitative record of the species composition, seasonal succession, vertical distribution, regional variation and seasonal cycles occurring in their phytoplankton. Frequently collected samples reveal differences and similarities in kinds and numbers of the dominating phytoplankton between the two study lakes. Samples from Hastings Lake show large numbers of individuals with low species diversity (66 species of phytoplankton) which is an indication of eutrophic conditions. Samples from Muir Lake show small numbers of individuals with a high species diversity (114 species of phytoplankton) which is an indication of oligotrophic conditions. Evidence, in the light of the results of this study, for and against the use of algal indicators of trophic lake types is given.

The succession of individual algal species and groups of algae within the two lakes is described. One of the factors suggested to be responsible for the rapid replacement of dominants within the phytoplankton community is the effect of extracellular substances. An inverse relationship appeared between the Cyanophyte, *Anabaena flos-aquae*, and several species of the Chlorophyta.

The motile and positively phototactic dinoflagellate *Ceratium hirundinella* and the buoyant blue-green algae, which form pseudovacuoles within their cells, were found to concentrate in the surface waters.

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Many of the Euglenophyta were distinctly bottom-water dwellers. Wind action, with the consequent mixing of the water, was responsible for maintaining a uniform distribution of most plankton algae as well as affecting their horizontal distribution.

Data on the physical, chemical and biotic factors are presented and relationships between these environmental factors and the seasonal cycles of the more abundant plankton algae are pointed out. Silica concentrations were inversely related to the periodicity of the diatom *Asterionella formosa*. The periodicity of the Chrysophyte *Dinobryon* in Muir Lake is discussed with respect to its correlation with the phosphate and bicarbonate levels. The seasonal cycles of the phytoplankton are grouped, for convenience in discussion, according to the time of occurrence of the cycle modes and the duration of the maxima.

The importance of winter studies to supplement the large amount of summer data now available, as well as a close and harmonious working of field and laboratory disciplines are stressed. The results of the present study are compared with those of other investigations on phytoplankton ecology.

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INTRODUCTION

Although the fund of information on the subject of algal periodicities is voluminous, little agreement has been reached between the various workers as to possible explanations of the observed events. The evolution of ideas to explain periodic cycling, seasonal succession and regional variations of algal populations itself tends to be cyclic. Those explanations or ideas which were fashionable and revealed the 'spirit of the times' in scientific thought were adopted by the many workers on the subject. In the late nineteenth century, and in the early nineteen hundreds, the physical environment, in particular water temperature, was thought to play the major role in controlling events, such as phytoplankton periodicities, that occurred in the lake. Then came the many arguments putting forward the idea that the chemical factors or physico-chemical factors are the major controlling influences in the population dynamics of algae. Here, the various chemical ions were considered to play roles of different importance. Nitrogen and phosphorus were thought to be two important chemical ions which controlled the seasonal cycles of many algae while silica concentrations were correlated with diatom periodicity. Just at the time when the influence of chemical factors was considered the best explanation of periodicities, the role of the biotic environment in algal ecology was brought forward. Many workers felt that the zooplankton in the lake were responsible for the waxing and waning of the phytoplankton crop. On the basis of recent knowledge acquired on the subject of algal periodicities, the limitations of the multiplicity of factors influencing these phytoplankton cycles

have been more fully realized. Current thought on the subject of algal periodicity is centered around the idea that, although the physical and chemical factors are responsible for the types and amounts of the different algae in a lake, and, to a large extent, the overall seasonal fluctuations, the algae themselves, are responsible for more subtle fluctuations in numbers. Certain species exhibit either an inhibiting or stimulating influence on themselves and on other algae through the action of extracellular substances which they emit.

The present investigation had two objectives. First, to obtain information on the seasonal succession, regional and vertical distributions and seasonal cycles of the phytoplankton of two lakes in central Alberta, Canada. Second, to correlate as closely as possible the observed events with prevailing ecological factors. For convenience, the subject matter of this thesis has been divided into three parts:

A. Species Composition and Seasonal Succession

B. Regional Variation and Vertical Distribution

C. Seasonal Cycles

Only those data employed directly in the main body of the thesis appear in the Results, while other data obtained appear in the Appendix.

LITERATURE REVIEW

A. Species Composition and Seasonal Succession

Phytoplankton distribution in time, or succession of the species present, is not only of interest in itself, but, since qualitative differences may have effects on the higher components of the food chain, is of economic importance (Fogg 1965). The general character of phytoplankton succession during the course of a year in the temperate regions of the world may be exemplified by the results of Rodhe *et al* (1958) for a eutrophic lake in central Sweden. In the years 1954 and 1955, diatoms made up the larger part of the standing crop of phytoplankton in April and May, being followed by flagellates, such as *Rhodomonas minuta* and *Dinobryon divergens*, and these organisms in turn followed by green algae and Cyanophytes in mid-summer. The seasonal succession of the diatoms is cyclic since they reappear in late autumn, while the seasonal succession of the blue-green algae is progressive since, upon gradual building up of numbers, a maximum is reached after which the cell numbers decline to nil, and these algae do not appear again until the following year (Pearsall 1932). "It will be obvious that the factors concerned in such a succession must be various and that the interactions between them are likely to be complex" (Fogg 1965). Different species have different temperature and light requirements, and it could be that a particular species predominates at a particular season because of the prevailing light and temperature conditions (Fogg 1965). Temperature and light requirements may explain the peculiar seasonal succession demonstrated by the species of the green alga *Spirogyra*.

"The species found first in the annual cycle are usually ones with narrow cells with a single chloroplast and replicate end-walls, while in summer, the wider celled species with several chloroplasts and plane end-walls develop, the order of appearance in the autumn being just the reverse. This seems to be the general rule and is correlated with the observations of Fritsch that the *Spirogyra* present in the tropics are mostly broad forms with two or more chloroplasts and plane end-walls" (Hodgetts 1922).

The variation in the concentrations of the available nutrients may be a factor in succession (Pearsall 1932, Hutchinson 1944, Rodhe 1948, Tucker 1957). The dominance of a particular alga is dependent upon its ability to successfully exploit the available nutrients at a faster rate than other algae with which it may be in competition. Certain algae are found to dominate over others even when the available nutrients are abundant (Lund 1964). The answer to the question of why does this occur can be found if we study the potential growth rates of the phytoplankton involved. Lund (1964) showed that if nutrient conditions are such that they are not limiting, the diatom *Asterionella* will always outgrow the diatom *Fragillaria*.

Other factors which may be important in succession are the effects of parasitism and selective grazing (Lund 1964). Fungal parasitism has been shown to have severe effects on algal populations, "but these effects are severe for short periods of time and rarely alter the main seasonal changes" (Canter and Lund 1951). Drastic reductions in the numbers of certain algae due to "over-grazing" by "selective feeding zooplankton" (Pennington 1941) has been discounted as a possible mechanism of algal depletion by Gibor (1956). Working with the brine shrimp

Artemia salina and several species of marine phytoplankton, Gibor (1956), showed that this zooplankter is not a differential feeder but ingests all algae (within a certain size range) and digests some algae more readily than others. Those species whose cells are not digestible have a distinct ecological advantage in that growth can resume while other species, which provided competition, are removed from the environment.

It has recently been suggested that extracellular organic substances are, to a major extent, responsible for the rapid replacement of dominants within a dynamic phytoplankton community (Hodgetts 1922, Akehurst 1931, Fogg 1965, Saunders 1957, Jørgensen 1957, Proctor 1957, Prescott 1960, Hartman 1960, and Vance 1965). Saunders (1957) has reviewed the studies on the interrelations of dissolved organic substances and phytoplankton and suggested that four functions of these substances may be involved: (a) they may have nutritive value for the algae, (b) provide accessory growth factors, (c) be toxic and antibiotic, and (d) cause chelation of trace minerals. Hartman (1960) has reviewed the evidence in support of the existence of organic metabolites produced by algae, examined the properties of these substances and considered the possible role of such substances as inhibitors, stimulators, or regulators of growth in natural populations. Although it has been adequately proven that these physiologically active substances exist both in the natural environment and in laboratory cultures of algae (Saunders 1957, Proctor 1957, Hartman 1960), "little has been accomplished in determining the actual chemical composition of the active substances or in understanding the nature of the physiological response of algae to these substances"

(Hartman 1960). Hartman also summarizes the work on the subject of the response of inter-acting algae to physiological stimulation or inhibition of growth. From this summary, "it appears that ample evidence now exists to indicate that many species of freshwater algae are capable of producing physiologically active metabolites which may function as toxins, growth inhibitors, or growth stimulators to themselves or to associated algae" (Hartman 1960).

Vance (1965) conducted investigations on Missouri ponds to determine whether physiologically active metabolic substances which are produced by algae, influenced the occurrence, composition and succession of Cyanophycean water blooms. During his investigations, Vance observed that when *Microcystis aeruginosa* was at its maximum peak, the blue-green *Aphanizomenon flos-aquae* was never abundant and vice-versa. Hammer (1964), when investigating Saskatchewan lakes, found many alkaline lakes to contain more than one bloom species but that each bloom was nearly unialgal. Blooms of *Anabaena* appeared first and were succeeded by *Microcystis* and *Aphanizomenon flos-aquae* blooms. *Anabaena* usually declined in numbers with or prior to the onset of other blooms" (Hammer 1964). The increased organic supply liberated by *Anabaena* may have been required by *Microcystis* and *Aphanizomenon* (Pearsall 1932). The sudden disappearance of a dense phytoplankton bloom is a commonly noted occurrence (Vance 1965) and this suggests the presence of some factor which inhibits the growth of the bloom species. The extra-cellular organic substances are likely involved and as Prescott (1960) said, "the plant in a sense, manufactures its own algicide". At the

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present time, it appears that long-chain fatty acids are involved in the inhibition (Hartman 1960). Rapid advances in chromatographic procedures for the identification of trace amounts of long-chain fatty acids should provide a definite answer to the interesting question of algal inhibitors and their role in the natural environment (Proctor 1957).

B. Regional Variation and Vertical Distribution

Regional Variation:

Many of the early limnological investigators assumed homogeneity in horizontal distribution of the phytoplankton in a body of water. Recently, "it has been well-established that the horizontal distribution of plankton is often irregular in lakes and varies within specific regions" (Gaufin and McDonald 1965). Kidd (1964) found that little similarity existed between the stations sampled at the same time within Glacier National Park lakes. Duthie (1965) showed that on the sediment of a small upland bog in North Wales, the concentration of desmids differed markedly even over small areas. Gaufin and McDonald report that the deviations found in the numbers of phytoplankton between stations in Deer Creek Reservoir, Utah, were large enough so that these could not be explained by simple inconsistencies in the counting technique. "In spite of these irregularities, the kinds and populations of plankters are quite similar in the main body of the reservoir" (Gaufin and McDonald). These authors state that the large inconsistencies in population size from one station to the next appear to be largely a matter of the location of stations sampled. The shallow water stations provided the large portion of the variation in distribution whereas the deep water stations were comparatively similar.

The reason for heterogeneity of plankton has been speculated on by Hutchinson (1953). He lists "light, temperature, humidity or density gradients, changes of state in certain directions, currents, winds, reproductive patterns (how close the offspring remain to the parent), social patterns, competition brought about by the interaction of species, and the laws of chance which affect the distribution of organisms" as possible causes of heterogeneity. Certainly, the striking horizontal distribution of the phytoplankton components of an algal bloom following a summer wind storm provides ample evidence of irregularities in horizontal distribution.

Vertical Distribution

Although overturns and other physical factors cause temporary displacement of algal populations in lakes of the temperate regions, most of the phytoplankton species show a tendency to occupy definite strata of water (Gaufin and McDonald). Small lakes that are shallow or subjected to strong winds often do not show significant vertical stratification of their phytoplankton (eg. Pennak 1949). Gaufin and McDonald report that in Deer Creek Reservoir, Utah, a few plankton algae such as *Anabaena* were primarily surface water forms while many species inhabited the "bottom waters" such as the diatoms *Stephanodiscus*, *Melosira*, *Cyclotella* and *Asterionella formosa*. Tucker (1957) shows the vertical-seasonal distribution of total phytoplankton, diatoms and Chrysophyceae in Douglas Lake, Michigan, and from the distribution of these phytoplankton species, states that "in general, each of the pulses first reached its maximum in the waters of the upper few meters, but soon afterwards, due to the stirring action in the water, the population tended to be distributed

almost uniformly from surface to bottom".

Willén (1961) studied the vertical distribution of phytoplankton extensively in several lakes in Sweden. In Lake Görvaln, Willén found that the algae were fairly evenly distributed during the vernal mixing of the water. In summer (July to the beginning of October) the "algal development was restricted to the trophogenic layer". At levels deeper than 10m, mainly diatoms and colorless flagellates predominated. "After the autumnal water circulation very low volumes of algae were recorded in winter and most of the organisms occurred in the level immediately under the ice" (Willén). In lake Osbysjön, this same author recorded a fairly uniform vertical algal distribution owing to the shallowness of the lake. Deviations were mainly observed in winter with Chlorophytes and Pyrrophytes concentrated immediately under the ice and with Bacteriophytes and Euglenophytes near the bottom. "In general, this distribution was caused by the light conditions and the concentrations of oxygen and hydrogen sulfide of the water" (Willén). In lake Sandängsfjörden a unique situation was observed by Willén. Both fresh-water and brackish water entered the lake and as a result of this union, the denser brackish water tended to settle to the bottom few meters of the lake. Fresh-water formed the upper few meters of the lake and "as a result of these environmental conditions the plankton populations were quite different in composition: fresh-water forms near the surface of the outflowing fresh-water, brackish water species and specific organisms adapted to low oxygen concentrations in the levels near the bottom" (Willén).

C. *Seasonal Cycles*

In some types of investigations it is a useful simplification to regard phytoplankton as a single homogeneous entity, for it is "largely true that the total biomass of phytoplankton is determined by the physical and chemical factors in the environment and is not dependent on the species which are represented in it" (Fogg 1965). "However, when the individual species comprising this mass of phytoplankton are considered, these are often found to replace one another as dominants with considerable rapidity, and the problem is seen to be more complex than a consideration of the total mass would suggest" (Hutchinson 1944). The problems of phytoplankton periodicities have attracted the attention of freshwater biologists for nearly a century, during which time many notable contributions have been made, such as Fritsch 1906, Transeau 1916, Hodgetts 1922, Pearsall 1932, Hutchinson 1944, Rodhe 1948, and Lund 1950,1954.

"Numberless studies of algal ecology (especially plankton) throughout the world have correlated algal abundance, pulses and periodicities with water temperature" (Prescott 1963). Chandler 1944, Leake 1945, Fogg 1952, and McCombie 1953, have stressed the importance of the physical factor of water temperature in determining the cycles of phytoplankton. "Although some close parallels have been drawn between 'optimum' high temperatures and phytoplankton pulses, seldom has any causal relationship been established" (Prescott 1963).

Since a good deal of the early literature on algal periodicities came from that part of the world where diatoms are usually abundant in

winter, it has been assumed that they require low temperatures for development. It is, however, not necessarily true that these diatom maxima are due to temperature conditions, and the existence of numerous exceptions make one suspect that the real underlying causes are factors which normally operate during cold weather, but which may have no causal connection with temperature (Pearsall 1923). The plankton diatom *Melosira* is abundant in Europe during the winter, while in North America it is abundant in summer, together with the Myxophycean flora. "It is clear then that *Melosira* may occur abundantly at any temperature found in normal surface waters" (Pearsall).

The physical factor of light intensity has been the object of many correlations with phytoplankton periodicities, particularily in the north temperate and arctic regions where light is highly limiting. Although light intensity directly affects photosynthesis, it was felt (Pearsall 1932) that perhaps the study of the chemical environment would provide clues for the elucidation of the problem of the direct cause of algal pulsation. Among the first reports on this subject was that of Fritsch (1906), who correlated the periodicity of *Spirogyra* with the total dissolved substances content of the water and found a positive relationship. Confirmation of this relationship was provided by the work of Hodgetts (1922).

Pearsall (1932) suggested further relationships between the chemical changes in the water and the seasonal cycle of certain phytoplankton species. He maintained that in the lakes of the English lake district, diatoms occurred only when the waters were richest in nitrates,

phosphates, silica and oxygen. The diatoms also preferred waters possessing a low basic ratio of $\frac{Na + K}{Ca + Mg}$ (below 1.5). Pearsall (1923) also showed that in water of similar geological origin, the proportions of nitrates and silica was higher in the most silted waters and the basic ratio was lower; a close correlation existing between the dissolved substances and the proportion of silt suspended in the water (substantiated by Chandler 1944). Pearsall also postulated that diatoms cannot reproduce appreciably when the concentration of silica is less than 0.5 mg per liter. Lund (1950) also found that when silica concentrations of the water in the English lakes reached 0.5 mg per liter or less, a sudden cessation of the diatom *Asterionella* occurred. However, he did not make the same commitment regarding phosphorus because he found that cells of this diatom could store phosphorus in excess of immediate requirements, even when the concentration of phosphorus in the water was 1 mg per liter or less. Hutchinson (1944) found the water of Linsley Pond, Connecticut, adequately supplied with the inorganic nutrients phosphorus, nitrogen, and silica, but lacked an abundant diatom population. Thus, he was rather doubtful of Pearsall's hypothesis. Jørgensen (1957) found that the "occurrence of large quantities of silicon in the lakes during the productive period is insufficient to start a great production of either plankton or epiphytic diatoms. It may be impeded by growth-inhibiting plankton algae".

In the English lakes, the populations of the Chrysophyte *Dinobryon* increase with a rise in the ratio of nitrate to phosphate and with a decrease in the amount of silica (Pearsall 1932). In Linsley Pond, Hutchinson (1944) found that *Dinobryon* increased with a rise in the

nitrate to phosphate ratio as pointed out by Pearsall, but not with a decrease in silica. Rodhe (1948) concluded, both from field observations and laboratory experimentation, that *Dinobryon divergens* and *Uroglena americana* prefer low concentrations of nutrients and are inhibited by rather small additions of phosphate. Rodhe found that, in Sweden, *Dinobryon* and *Uroglena* occurred only in lakes which are not exposed to enrichment of nutrients, (especially phosphorus and nitrogen) by human habitation. Thus, these two genera were completely lacking in polluted waters. Pearsall (1932) noted that a fall in calcium seemed to favor an increase in the numbers of *Dinobryon* . Conversely, Tucker (1957), while working on Douglas Lake, Michigan, found that rising levels of calcium (as determined by bicarbonates) favored *Dinobryon*.

A high concentration of organic matter has been correlated with abundance of blue-green algae (Pearsall 1932, Hutchinson 1944, Tucker 1957, and Vance 1965). Other authors such as Duthie (1965) report a negative correlation between the organic matter content and the abundance of blue-green algae. Duthie claims that, in the lakes he studied in North Wales, the Chlorophyceae, flagellates and diatoms are favored by highly organic waters.

Very little is known about the chemical factors controlling the populations of the green algae in natural waters. Tucker found that in Vincent Lake, Michigan, the green algae, although never abundant, seemed to be favored by high concentrations of organic matter. Pearsall reported that the green algae in the English lakes occurred during periods when the concentration of nitrates and phosphates in the water

was low and the organic matter content high. Rodhe (1948), however, found that the nitrogen requirement of the green alga *Scenedesmus quadricauda* is much too high to be satisfied by the concentrations available in most natural waters. "The cell increase, the substance production, and the formation of chlorophyll are affected by nitrate deficiency as observed in culture experiments" (Rodhe).

The dinoflagellate *Peridinium wisconsinensis* was found by Tucker to be fairly abundant (17% of the total phytoplankton) in northern Michigan lakes that possessed a pH which was slightly acid and an extremely low bicarbonate content. If this species is generally found in waters having these same chemical characteristics, it might be a useful biological index. Many plankton algae have been listed as indicators of trophic lake types but have been useful only to a limited degree (Rawson 1956).

The general consensus as to the role of the various environmental factors controlling phytoplankton periodicities is that the physical and chemical factors act synergistically to control the time of occurrence of a phytoplankton pulse, and, to a certain extent, its magnitude, while the biotic factors (inhibitors, stimulators, grazers, parasites, etc.) largely control the magnitude of the pulse.

METHODS

A. Field

1. General

The period of this investigation extended from May 1, 1965 to June 30, 1966. Fieldtrips were made weekly in the spring, summer and early fall, biweekly in the late fall, and monthly in winter. Phytoplankton counts were made on six hundred samples.

Two sampling stations for quantitative investigation were established on Muir Lake, three on Hastings Lake. On both lakes one of these stations represented the deepest point of the lake and all stations were situated in the limnetic region. The two lakes were visited on successive days.

2. Physical Features

Stakes and gauges for measuring water level fluctuations were set up at both lakes in early May, 1965 and water level records taken during each fieldtrip.

A sampling routine was established such that a given station would be sampled at approximately the same time of day on each successive fieldtrip. Weather conditions were noted during each sampling.

Water temperature profiles were obtained using a good grade mercury thermometer. The thermometer was set in a vacuum bottle by a one-hole rubber stopper. Water samples were obtained by lowering a 2-litre Kemmerer water sampler slowly to the desired depth in the open position, allowing it to remain at this depth for one minute for temperature

stabilization, closing it by the messenger and bringing it to the surface rapidly. An aliquot was then poured into the vacuum bottle and the temperature recorded.

Snow and ice cover were recorded during each winter fieldtrip.

Transparency was measured with a Secchi disc of 20 cm. diameter.

Line soundings of Muir Lake supplemented sounding data provided by the Fish and Wildlife Division, Alberta Department of Lands and Forests. Sounding tapes taken with a Bendix DR-19 Marine depth recorder were provided for Hastings Lake by Joseph Kerekes, Department of Zoology, University of Alberta. Soundings were plotted on maps redrawn from aerial photographs provided by the Alberta Department of Lands and Forests.

3. Chemical Features

Chemical analysis of the water was conducted in the field using a Hach Chemical Direct Reading Model DR-EL portable water chemistry kit. This kit is equipped with a photocell for colorimetric tests and the necessary reagents for many volumetric chemical tests which can be carried out in the field with considerable accuracy. "On the spot" analysis in the field is much preferable to the testing of water samples in the laboratory because of the many changes that occur during sample transport. For example, iron and manganese will plate on the inside of sample bottles. Silica concentration will usually change if glass containers are used as sample bottles. Phosphate readings between field and laboratory often differ. The gasses oxygen, carbon dioxide, hydrogen sulfide, and chlorine will either evaporate or dissipate. Those components of lake waters which

could not tolerate transport to the laboratory were analyzed for in the field. Tests other than the above mentioned ones were conducted in the laboratory.

Basically, the tests employed are those outlined in American Public Health Association - Standard Methods (1965). Some tests were simplified in procedure to enable relative ease of operation in the field. For example, no acids were added to the water sample prior to analysis for metal trace elements. Before tests for metals as trace elements are normally conducted in the laboratory, strong acids are added to the water samples to digest free organic matter which may interfere with the analysis. Failure to execute this step decreases the precision of the test but I feel that the interference of organic matter in analysis for trace metals plays a much smaller role in decreasing accuracy of the test than the loss of such trace metal ions by plating on the sample container during transport to the laboratory. I feel that the advantages offered by such a chemistry kit far outweigh the disadvantages.

Table 1, page 18, lists the chemical analysis conducted, the test method and the depth at which the sample was taken.

Precautions were taken, where possible, to minimize the effects of test interference. Samples near the bottom muds were passed through filter paper before tests other than those for gases were performed. During times of abundant and heavy plankton growths, all the water samples were filtered prior to chemical analysis.

Complete chemical analyses were made on water samples from one fixed station at each study lake. Water samples from other stations were

TABLE 1

Chemical Test Methods And Depth Of Sample Analyzed

Analysis	Test Method	Depth Of Sample
Alkalinity	Standard Titration	**Surface
Chlorides	Mercuric Nitrate Titration	Surface
*Chlorine	Orthotolidine	Surface
Chromate	Hexavalent Chromium	Surface
Copper	Cuprethol	Surface
Hardness	Titrimetric	Surface
*H_2S	Hach Chemical	Every Meter Under Ice
*CO_2	Standard Titration	Surface & Every 2M
Sulfate	Turbidimetric	Surface
*Iron	1,10-Phenanthroline	Surface & Bottom
*Manganese	Cold-Periodate Oxidation	Surface
Nitrate-N	Chromatrophic Acid	Surface
Nitrite-N	Azo Dye Formation	Surface
*Phosphate (Ortho)	Stannous Chloride	Surface
Phosphate (Meta)	Hydrolyzed S_n Chloride	Surface
*Silica	Colorimetric Heteropoly Blue	Surface & Bottom
*pH	Colorimetric	Surface & Bottom
*Dissolved Oxygen	Modified Winkler Method Colorimetric	Surface & Every 2M

* Denotes tests conducted in field under all weather conditions

** Surface sample actually taken 5-10 cm below surface

obtained for selected chemical tests such as dissolved oxygen, carbon dioxide, iron, silica and total dissolved substances.

Two-liter surface water samples were collected and transported to the laboratory in polyethylene bottles. Tests not conducted in the field were completed in the laboratory immediately upon return.

The Hach Chemical analysis kit was not equipped for the following tests: total dissolved solids (T.D.S.), organic matter, magnesium, calcium, bicarbonate, carbonate, potassium, and sodium ions. These tests were conducted by the Provincial Analyst, University of Alberta, Edmonton. In addition, as a check on results, the Analyst performed those tests already completed using the Hach kit.

Bottom samples of mud were obtained with a 9 inch square Ekman dredge. These samples were transported in polyethylene bags to the laboratory where they were placed in pans to air-dry at room temperature. The dried mud samples were then chemically analyzed by the Agricultural Soil and Feed Testing Laboratory, University of Alberta, Edmonton.

4. Aquatic Macrophytes

The distribution of the aquatic macrophytes in both lakes was mapped and the species present were given relative abundance values. Deeply submerged macrophytes such as *Najas flexilis* and the many *Potomogeton* species were collected by means of a grapple hook.

5. Phytoplankton

(i) Qualitative

All algae were studied in the living condition. Hand-grab collections

were made along the lake margins. Qualitative phytoplankton samples were made by towing a plankton net of #20 bolting silk gauze through the water. Large mats of blue-green algae (mostly *Oscillatoria spp.*) were collected as these mats floated at the surface. Bottom muds were sampled and their algae investigated.

A number of submergent and emergent aquatic macrophytes were collected and their attached algae observed. Such aquatics included *Potamogeton pectinatus*, *P. vaginatus*, *P. richardsonii*, *Utricularia vulgaris var. americana*, *Myriophyllum exalbescens*, *Nuphar variegatum*, *Equisetum fluviatile*, and *Typha latifolia*.

(ii) Quantitative

Quantitative samples were taken with the Kemmerer water sampler from every meter of the water column. Hand scoop collections were taken from the surface layer. When the water samples were brought to the surface, the water bottle was shaken vigorously and an aliquot was poured into a 500 milliliter glass sample bottle. The samples were placed into an ice chest for transport to the laboratory. In the laboratory they were stored at 4 degrees C until concentration. In winter quantitative samples were taken through a hole bored into the ice by an ice-pick.

B. Laboratory

1. Qualitative

Qualitative samples were observed under 100X, 300X, 400X and 1,000X (oil immersion) magnification and the identified algae listed. In this list were included nannoplanktonic algae such as *Kirchneriella spp.*

Plate 1. Winter fieldwork and equipment at station 2 on Hastings Lake showing the hole bored through 40.6 cm of ice.

1.

and *Tetraëdron minimum*, which could not be recognized under the magnification employed in counting.

2. Quantitative

(i) Concentration

The plankton for quantitative enumeration was concentrated by centrifugation using a Servall temperature controlled centrifuge. One major disadvantage of this large centrifuge was that only small volumes of the original water sample could be used at any one time.

Each of eight tubes had a maximum efficient capacity of 30 milliliters. Two such tubes were used for each sample. The samples were centrifuged with a centrifugal force of 19,000 g for a period of 20 minutes at 4 degrees C. The tubes were then removed and 27 milliliters of supernatant were withdrawn carefully, leaving 3 milliliters of concentrate in each tube (10X concentration). Four of the 6 milliliters of concentrate were used for enumeration purposes.

The algal concentrate was found to adhere strongly to the bottom of the centrifuge tubes. In order to resuspend the cells the tubes were allowed to remain undisturbed at room temperature for 30 minutes, after which time the concentrate was agitated by swirling the tube.

One purported disadvantage of the centrifugation method of concentrating plankton is that it is an inefficient means of concentrating those algae possessing a very low specific gravity. Only two such algae were found during this study- *Microcystis aeruginosa* and *Aphanizomenon flos-aquae*.

Cells of both of these blue-green algae produced pseudovacuoles during the summer which resulted in their extremely low specific gravity. The inefficiency of concentrating these two algae led me to eliminate them from quantitative studies.

Re-centrifugation of the supernatant from the first centrifuge run recovered little or no phytoplankton.

(ii) Enumeration

A standard Sedgwick-Rafter counting cell was used in making the enumeration of algae. The concentrate was thoroughly mixed by blowing air in gently with a sterile wide-mouth pipette. While the concentrate was still agitated, a one milliliter portion was withdrawn with the same pipette and this aliquot introduced into the Sedgwick-Rafter cell. A cover slip which had been lying diagonally across the cell was allowed to move into place during the operation. After allowing the concentrate to settle for 30 minutes, enumeration was carried out.

Counts were made using a 10X objective (17 mm) and a 10X ocular. A Whipple ocular micrometer was employed to delimit the fields within the counting cell.

Kutkuhn (1958) applied standard statistical techniques to the distribution of phytoplankton counts made using a number of subsample mounts and a number of micrometer field combinations. Based on the results of his statistical analysis, Kutkuhn states that "the most practical subsampling ratio from the standpoint of increasing the precision of overall numerical estimates without expending additional

time and labor appeared to be four cell mounts and ten micrometer fields per mount". This recommendation was practiced in my quantitative counts. Four Sedgwick-Rafter cell mounts were made and ten random fields per mount selected and the algae counted. Numerical estimates for each species counted were recorded as the number of cells and units per milliliter of sample. Multiplication factors were drawn up for calculating cell numbers per unit of colonial and coenobial forms and are shown in Table 2, page 25.

Certain algae were somewhat "atypical" in morphology when they first appeared in the flora. These species were recorded by means of drawings and identifications made later as more characteristic features developed.

3. Culturing

Water samples were set out in large glass jars to which was added a culture medium consisting of Bristols solution and soil-water extract in the following proportions:

Water Sample-------------------------	1.50 liters
Bristol's Solution-------------------	.50 liters
Soil-Water Extract-------------------	.20 liters

These cultures were kept on a window bench with a western exposure at room temperature. The cultures were first examined microscopically when a growth of algae visible to the naked eye was observed. At no time were cultures examined before a four week culture period had elapsed. Water samples from each winter collection and occasional summer or fall collections were cultured in this way.

Ice samples from 0.5 meter depth were collected in the winter and the meltwater cultured as above. The numerous algae that developed were recorded along with a note of their relative abundance.

TABLE 2

Cell Number Per Unit (Colony Or Coenobium)
And Multiplication Factor Used In
Calculating Cell Numbers

Alga	Cell Number/Unit or Multiplication Factor
Actinastrum	8
Anabaena	40
Ankistrodesmus	8
Asterionella	8
Chroococcus	9
Coelastrum	40
Coelosphaerium	128
Crucigenia	4
Merismopedia	16
Oocystis	4
Pandorina	16
Pediastrum boryanum	36
Pediastrum duplex	36
Pediastrum obtusum	8
Pediastrum tetras	4
Scenedesmus	4
Selenastrum	20
Synura	24
Tabellaria	8
Tribonema	15
Uroglenopsis	200

DESCRIPTION OF STUDY AREAS

I General Features of Both Areas

1. Geographic Location

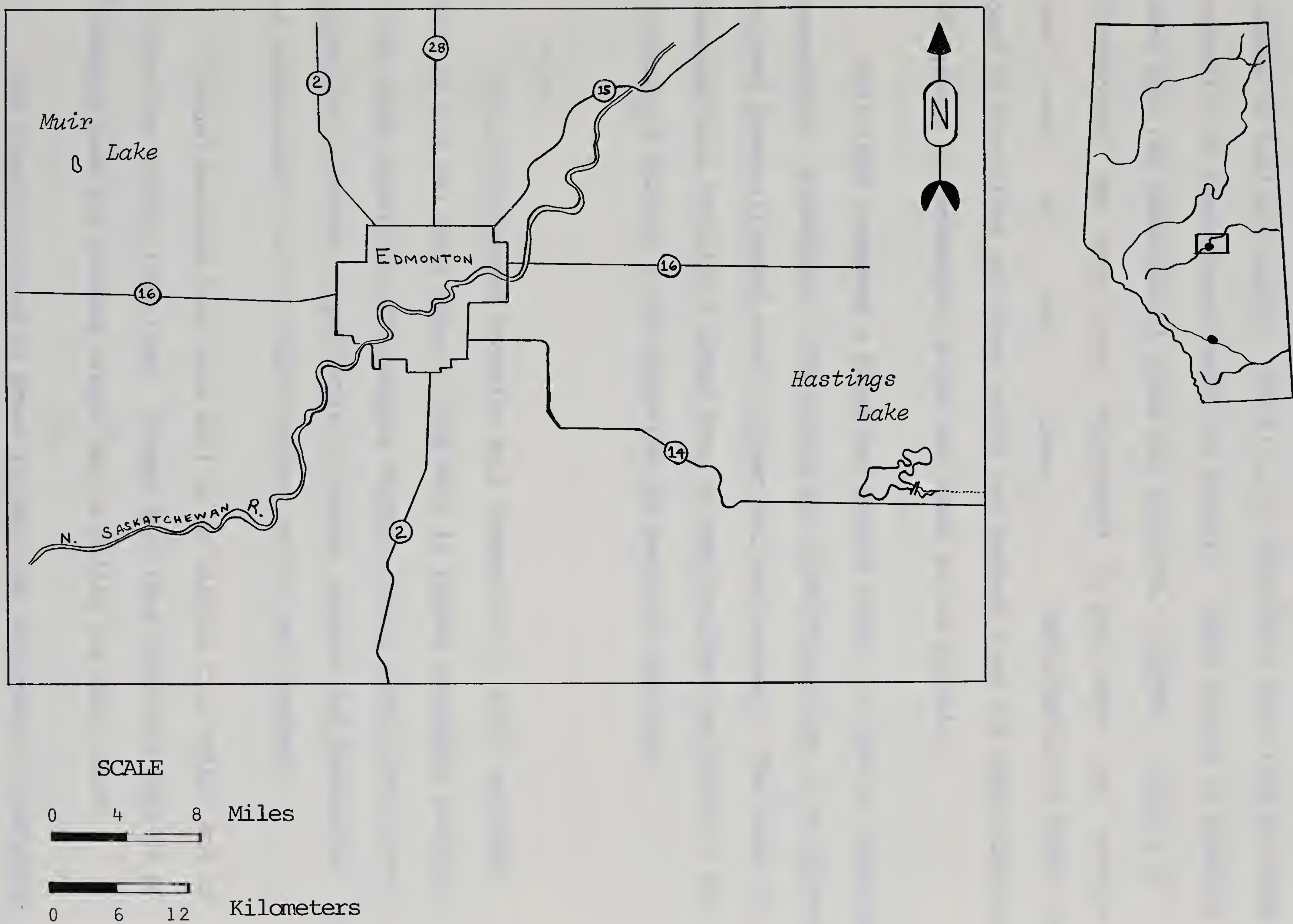
Muir Lake is located between longitudes 114°00′ and 113°55′W and latitudes 53°35′ and 53°40′N. Hastings Lake is located between longitude 113°00′ and 112°50′W and latitudes 53°15′ and 53°30′N. The lakes are in the geographic centre of the province of Alberta and lie in an area of a moderately populated mixed farming community. The city of Edmonton lies 35 kilometers E-SE of Muir Lake and 50 kilometers W-NW of Hastings Lake.

2. Geology

The area of the two study lakes was heavily glaciated during the Wisconsin time by a continental glacier (Bayrock and Hughes 1962). This glacier covered most of Alberta and its retreat from central Alberta was mainly by "stagnation." The recession of the glacier was rapid, resulting in new lakes with a drainage pattern that followed the direction of glacial retreat. Muir and Hastings Lakes are two of these postglacial lakes.

Immediately surrounding the water margin of Hastings Lake lie bottom-land deposits of clay, silt, sand, muck and marl deposited in recent times. Beyond these deposits lie what is termed "hummocky dead-ice moraine" (Bayrock and Hughes 1962) which is composed of till with minor pockets of sand and gravel. The main topographic features of this hummocky deadice moraine are knobs, kettles and till ridges.

Figure 1. Location Of The Two Study Lakes In Relation To The City Of Edmonton.


Muir
Lake
EDMONTON
N. SASKATCHEWAN R.
Hastings
Lake
N
28
2
15
16
16
14
2
SCALE
0 4 8 Miles
0 6 12 Kilometers

Muir Lake lies in a similar hummocky dead-ice moraine of till with lenses of sand and gravel. The hills in which Muir Lake lies are made up primarily of Saskatchewan sands and gravels. Their origin is doubtful since more than one depositional cycle was involved. However, fossils of Pleistocene age have been discovered in the sands and gravels just west of Muir Lake . The gravels are mainly composed of quartzites and chert which was derived from the Rocky Mountains. No igneous or metamorphic rocks are found in the gravels.

Muir Lake possesses a black mud bottom which is low in nutrients, especially phosphorus. The bottom mud of Hastings Lake is of lighter colored brown silty-mud with a higher nutrient content. The basin of Hastings Lake contains a large area of huge boulders and rocks in the vicinity of Station 3 but otherwise the basin is rock-free.

3. Soils

Orthic Grey Wooded Podzolic soil (Bowser *et al* 1962) surrounds most of the two study lakes. This soil is formed on medium textured (clay loam) material that contains stones. "It is a soil low in many plant food elements in particular nitrogen, sulphur and phosphorus." It is exceptionally low in organic matter and is well drained.

Around Hastings Lake this soil is of "glacial till origin" and is called the Cooking Lake Loam. Around Muir Lake this soil type is of "hummocky dead-ice moraine origin" and is called the Glory Loam.

One other soil type is found in the area north-west of Hastings Lake. This soil is a solonetzic rather than a podzolic soil. It is a

much more arable soil than the Grey-Wooded Podzol. Solonetzic soils are well-to-imperfectly drained soils which have an exchangeable base status in which the ratio of calcium to magnesium and sodium is usually one. This soil type extends along approximately 1.4 miles (2.2 kilometers) of shoreline.

4. Climate

(i) General

The macroclimate of the area encompassing both study lakes is assumed to be uniform. It is described as a cold, temperate continental climate characterized by relatively warm summers and cold winters. Climatological data was obtained during the course of this study from the nearest weather station which was located at the Edmonton Municipal Airport (53°35'N, 113°30'W, elevation 2200 feet). These data are summarized in Table 3, page 30.

(ii) Air Temperature

Generally, the period of study was colder than average. The mean 1965 summer air temperature, May to September inclusive was 54°F, two degrees below the long term average. July was the warmest month with an average temperature of 65.4°F. January was the coldest month of the study and the sixth coldest on record.

(iii) Precipitation

Monthly precipitation records for the period of study are shown by Figure 2, page 31. The mean annual precipitation for 1965 was 21.43 inches. The long time average is 18.64 inches. The long time

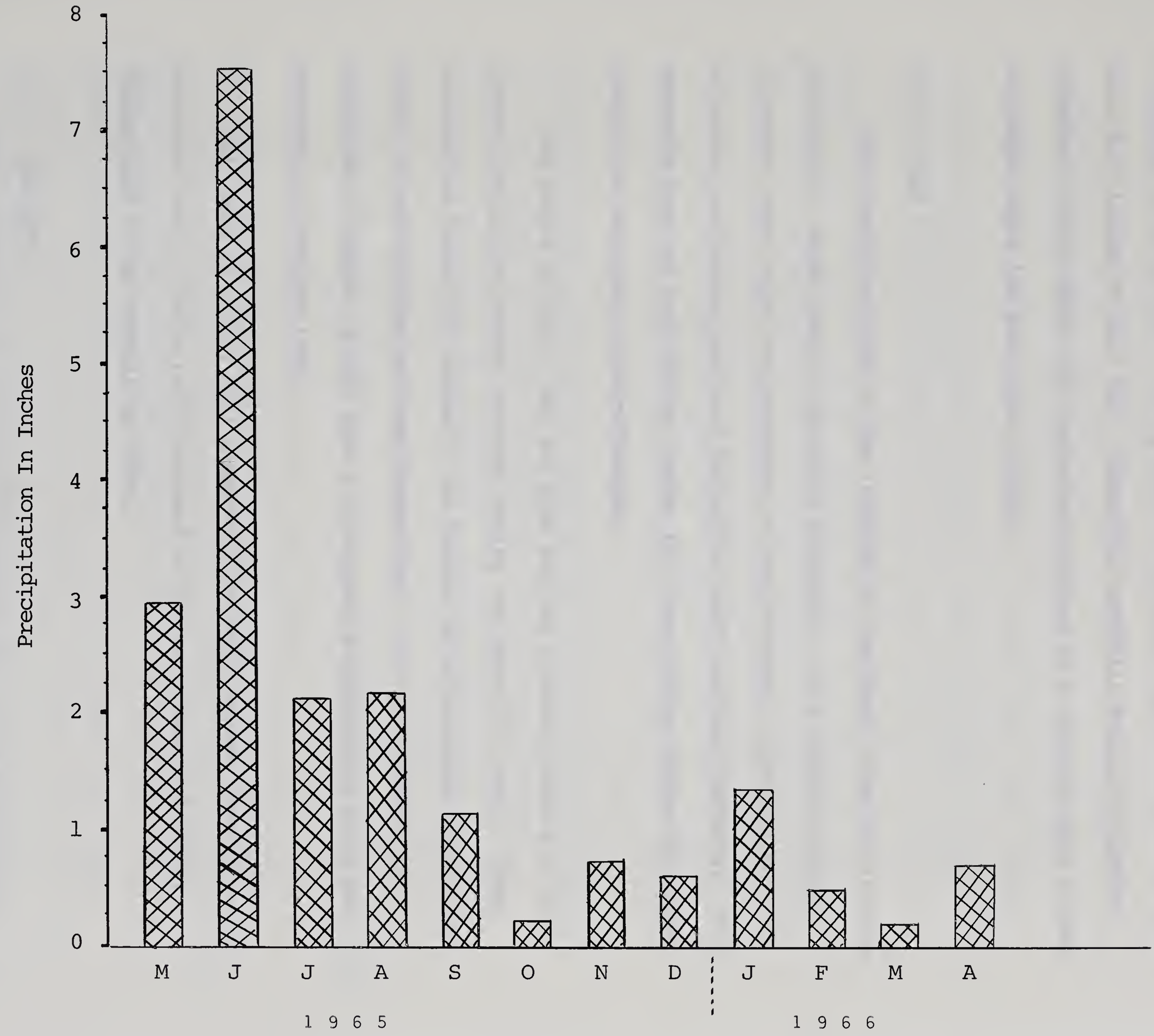
TABLE 3

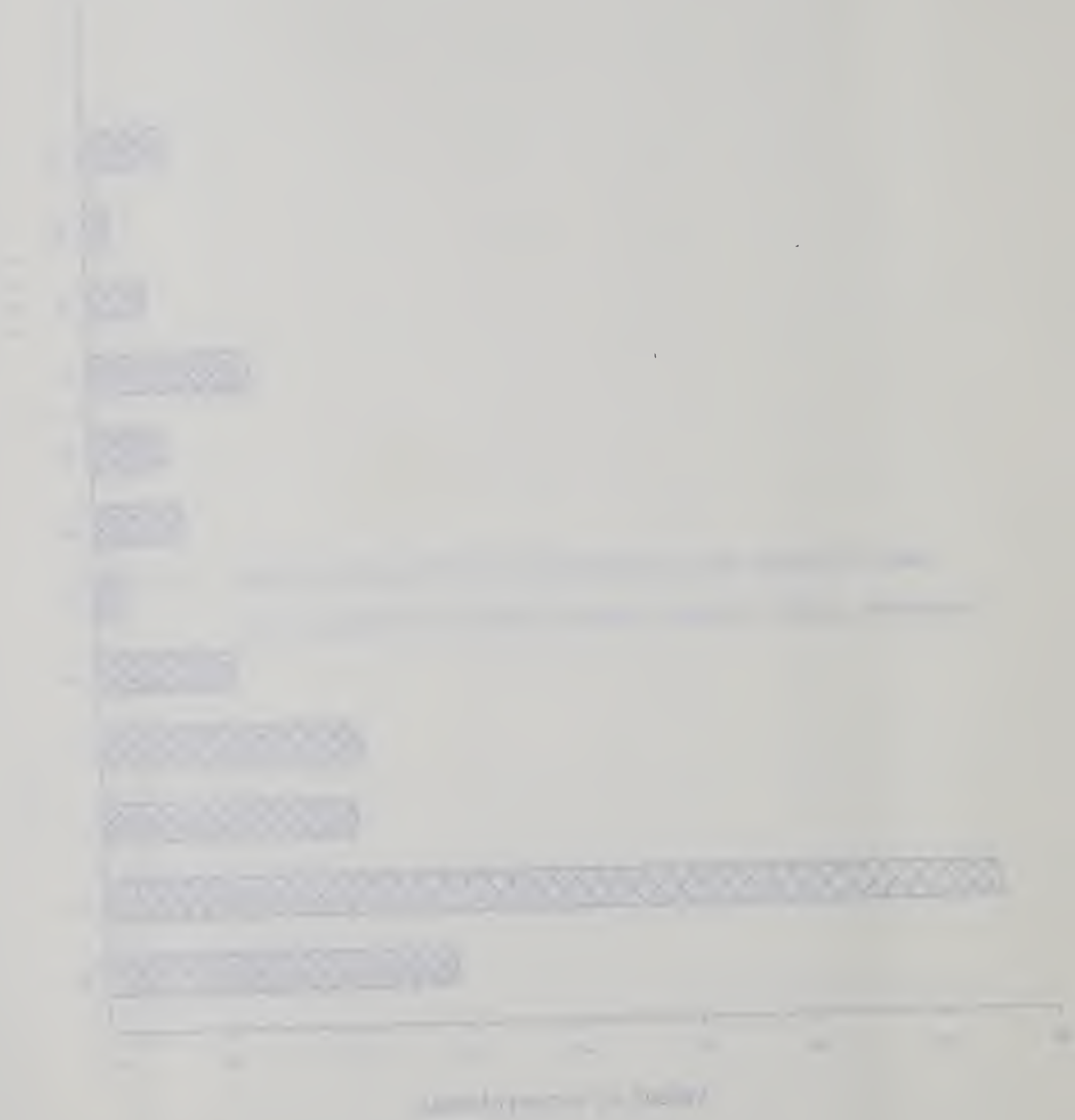
Meteorological Summary For The Period From June 1965 To May 1966
With Long-term Averages (Edmonton Public Weather Office)

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APRIL	MAY	MEAN
MEAN TEMPERATURES (°F)													
1965-66	57.8	65.4	64.5	43.3	47.4	19.5	13.5	-8.3	13.4	24.5	33.7	54.3	35.8
*Average	57.8	63.1	60.0	51.5	41.2	24.5	13.3	6.6	11.2	22.1	39.5	52.1	36.9
TOTAL PRECIPITATION (in.) (10" snow= 1" rain)													TOTAL
1965-66	7.48	2.11	2.14	1.10	.22	.71	.66	1.39	.50	.02	.73	1.11	18.17
*Average	3.15	3.34	2.55	1.35	.90	.88	.99	.95	.77	.83	1.10	1.83	18.64
WIND SPEED (mph)													MEAN
1965-66	10.60	7.7	9.0	9.1	9.0	7.3	7.3	8.3	7.5	8.6	10.7	11.7	8.9
*Average	9.80	8.9	8.3	8.9	8.8	8.2	7.7	7.8	8.0	8.9	10.4	10.5	8.9
TOTAL HOURS OF BRIGHT SUNSHINE (hrs)													TOTAL
1965-66	261.1	316.8	263.9	142.2	205.7	73.5	108.2	67.6	119.9	178.6	217.5	320.5	2272.5
*Average	254.1	309.2	270.0	187.9	158.4	101.4	77.5	68.2	114.7	166.2	222.0	266.0	2213.6

* Long-term Average (1881-1965)

Figure 2. Monthly Precipitation Histograms For The Period Of Study (Data Supplied By Dominion Public Weather Office, Edmonton.)


Precipitation In Inches
0
1
2
3
4
5
6
7
8
M
J
J
A
S
O
N
D
J
F
M
A
1 9 6 5
1 9 6 6



average is 18.64 inches. The greatest monthly precipitation came in June when 7.48 inches of rain fell. Excessive snowfalls during the period November 1965 to March 1966 inclusive resulted in a total of 89.4 inches-35 inches above the long time average.

(iv) Wind

The prevailing winds at the latitude of the study lakes are from the north-west. Winds tend to be cyclic diurnally. On a typical warm day in summer these winds are strongest in the afternoon, light in the late afternoon and evening and calm during the night and early morning. This sequence does not hold during storms, but, even during storms the winds tend to be strongest in mid-afternoon.

The months of April, May and June had the greatest amounts of wind. Several major wind storms occurred during the period of study. These occurred on August 13, October 1 and October 30 with maximum wind gusts of 62, 70 and 65 miles per hour respectively. It was following the windstorm of August 13 1965 that a blue-green phytoplankton bloom was observed at Hastings Lake.

Muir Lake is fairly well protected from winds except from the north. Hastings Lake, by being partly exposed to the north-west, is highly susceptible to the prevailing winds.

(v) Sunlight

The latitude of the study areas provides for a long daylength of bright sunshine during the summer season. Above average totals of sunshine hours were found for the months of March, October and December 1965 and March 1966.

5. Terrestrial Vegetation

The two study lakes are located in a vegetation zone regarded as the Boreal-Parkland Transition (Moss 1955). The forest, predominantly Parkland Poplar, consists of five strata: (a) the taller trees, *Populus tremuloides* and *P. balsamifera*, forming a nearly continuous canopy; (b) smaller trees and taller shrubs, *Amelanchier alnifolia*, *Shepherdia canadensis*, *Symphoricarpos albus*, *Lonicera involucrata*, and *Cornus stolonifera* comprising the intermittent layer; (c) lower shrub layer, *Ribes spp.*, and *Rosa acicularis*; (d) taller herbs such as *Aster ciliolatus*, *Vicia americana*, *Epilobium angustifolium*, *Galium boreale*, and *Calamagrostis canadensis*; and (e) lower herbs such as *Pyrola asarifolia*, *Viola rugulosa* and *Fragaria virginiana*. The latter stratum includes the mosses *Hylocomium splendens* and *Ptillium crista-castrensis* and other cryptogams which form extensive carpets in moist areas.

Natural succession of poplar to white spruce (*Picea glauca*) has advanced to varying degrees around the study lakes and farther on islands within the lakes. Hastings Lake in particular, contains many islands where white spruce is well developed and is the dominant tree. These islands are well protected from agents of destruction and serve as an example of what the surrounding countryside would be like had biotic and pyric factors not suppressed the maturation of the forest to the point where white spruce dominates. The snowshoe rabbit and other animals have caused considerable damage to young spruce seedlings. Burning, while only temporarily setting back the sucker-regenerating poplar, is devastating to the seed-regenerating white spruce. It is this latter factor that has contributed most to the retention of the poplar as the dominant tree species in the area of the two study lakes.

II. Features of Muir Lake Study Area

1. Physical Features

Bathymetric contour lines together with the sites of the sampling stations are given in Figure 3, page 35. Complete morphometric parameters are shown in Table 4, page 36.

The main sources of water income for Muir Lake are surface drainage, ground water and precipitation falling on the water surface. Since the lake basin lies in the center of a rise of land surrounded by hills in close proximity, it has a very small watershed area which extends for only a few square miles. This small watershed area contributes largely to the nature of the water chemistry and phytoplankton of the lake. The mode of entry of ground water into the lake is doubtful. There is some evidence to support the claim that discrete springs enter the lake floor (Carefoot 1959). The small surface area of the lake,and the very impervious Saskatchewan sands and gravels that surround the lake, provide conditions for a rapid reaction of water levels to rainy periods.

A very small intermittent creek provides the lake with an outflow which is of an extremely minor consequence since it did not contain water during the study period. Drainage (through this intermittent creek and seepage) eventually reaches the Big Lake drainage system which terminates in the North Saskatchewan River.

The seasonal water level fluctuation for the period of study is shown by Figure 4, page 39. The 1965 spring runoff produced a rise of 7.9 centimeters in water level and it is assumed that the income from the 1965

Figure 3. Bathymetric Map Of Muir Lake Showing Sampling Stations And Water Level Gauge Site. Contour Interval 1 Meter.

MUIR LAKE

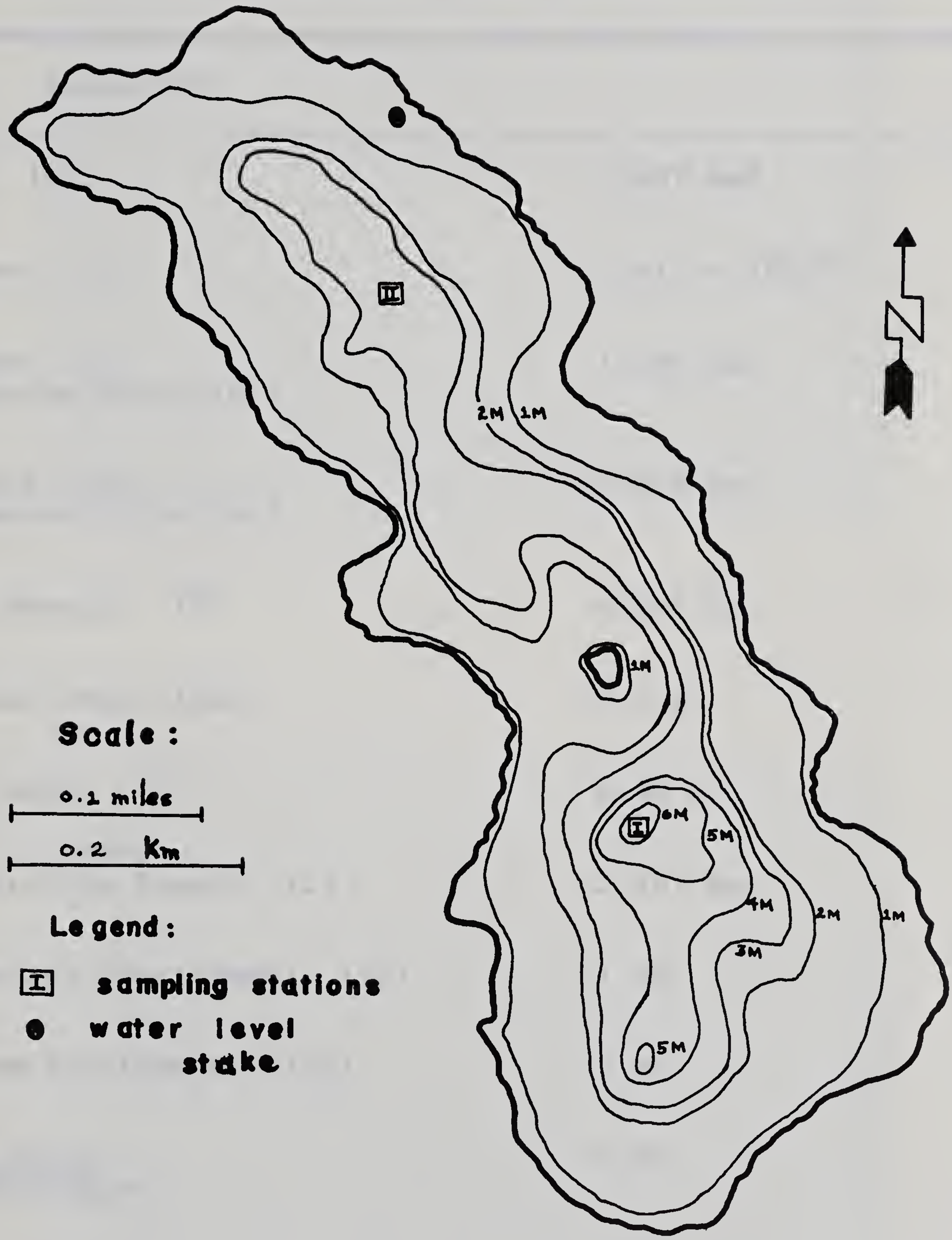

2M
1M
1M
6M
5M
4M
2M
1M
3M
5M
Scale:
0.1 miles
0.2 Km
Legend:
sampling stations
water level stake

TABLE 4

Morphometry Of Muir Lake

Parameter	
Area (Az)	0.287 km^2
Volume (V)	0.817 x $10^6 m^3$
Length (l) (Maximum Effective)	1.089 km
Breadth (bx) (Maximum Effective)	0.378 km
Mean Breadth ($\bar{b}$)	0.263 km
Maximum Depth (Zm)	6.1 m
Mean Depth ($\bar{Z}$)	2.85 m
* Shoreline Length (L)	3.137 km
Shoreline Development (D_L)	1.70
Volume Development (D_V)	1.40
$\frac{\text{Mean Depth}}{\text{Maximum Depth}}$	0.46
Elevation	738.2 m

* Excluding Island

Plate 2. Muir Lake as viewed from the north-west on May 1, 1966.

Plate 3. Muir Lake as viewed from the same location as shown in Plate 2. Photograph taken on May 26, 1966.

2.

3.

spring runoff was of the same order. The effect of runoff on the water level of the lake was small in relation to the effect of the heavy rainfall during the final week in June as caused by the above average rainfall for the area (Figure 2, page 31). During this period, the level rose from +11.20 centimeters to +43.47 centimeters. This sudden increase resulted in the indundation of the old shoreline now covered with terrestrial vegetation. The taller terrestrial plants were partly covered with water while the low growing forms were totally submersed.

Seasonal and vertical temperature profiles are given for station 1 in Figure 5, page 40. When the study began, the water temperature profile indicated that the condition of spring homothermy existed. Two weeks later (June 30) the vertical water temperature series demonstrated the start of summer stratification. Thermoclines developed between three and four meters on at least three sampling dates during the summer. These were July 7 (d profile line), July 21 (f), and August 4 (h). The differance in temperature between the upper and lower limits of the thermoclines were 4.5°C, 3.4°C, and 3.8°C respectively. The maximum surface water temperature for station 1 was recorded as 24.5°C on August 4. Frequent winds throughout the summer months prevented the formation of stable thermoclines. No thermocline was found to endure for a period beyond two or three weeks.

Homothermy was re-established between August 26 and September 1. The water temperature dropped steadily from this point until freezeup. At no time during this period of homothermy was the difference between the surface water temperature and that of the bottom more than 1°C.

Figure 4.

Changes in The Water Level of Muir Lake for The Period May 1965 to June 1966

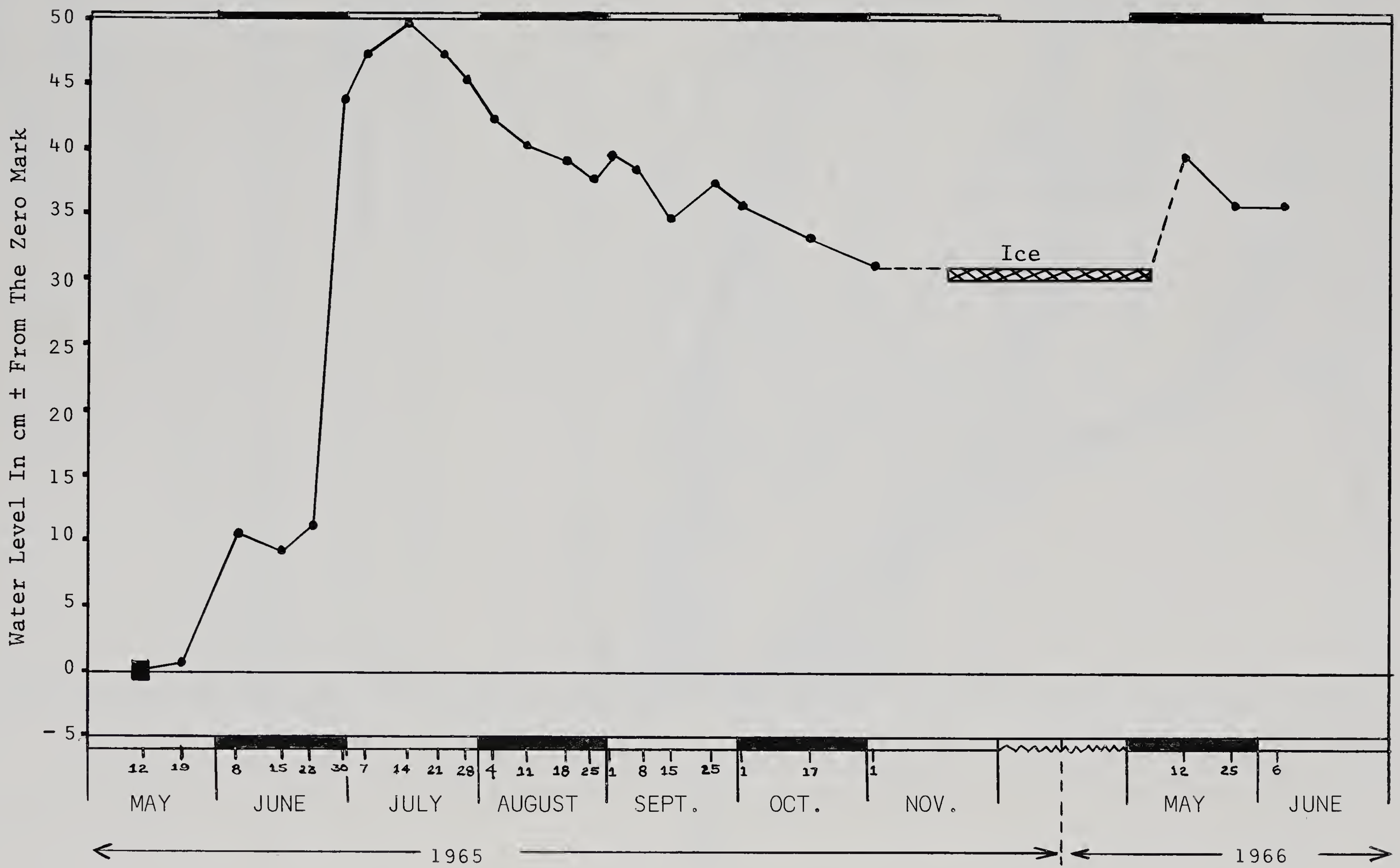
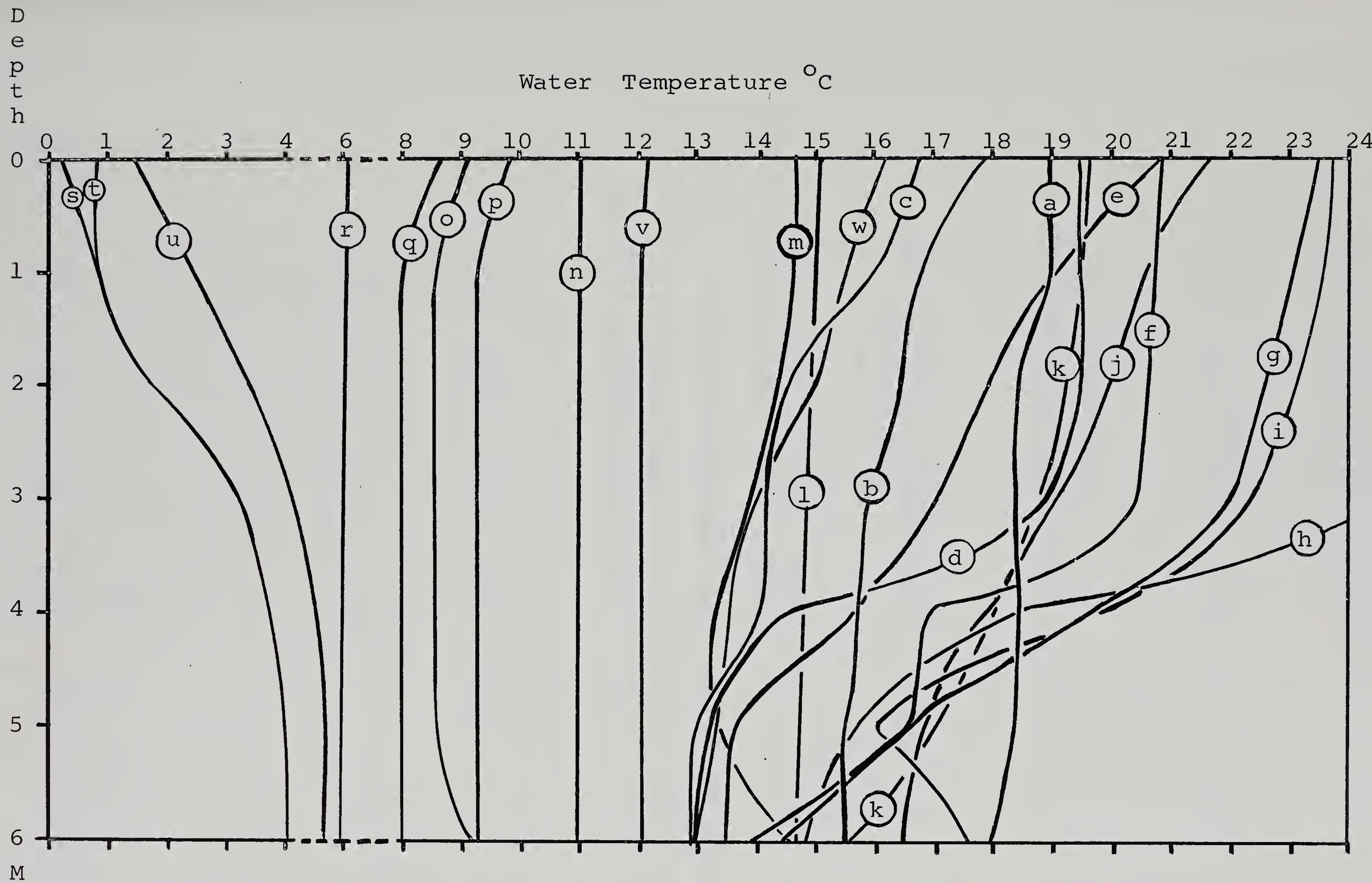


Figure 5. Seasonal water temperature profile for station 1 in Muir Lake. For key to profile lines, see Table 5, page 41.



Water Temperature °C
Depth
M
0
1
2
3
4
5
6
0
1
2
3
4
6
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r
s
t
u
v
w

TABLE 5

Seasonal And Vertical Water Temperature Series For

Muir Lake From June 15, 1965 to May 26, 1966.

MONTH	KEY	DATE	0	1	2	3	4	5	6
JUNE	a	15	19.2	19.5	18.5	18.8	18.5	18.3	18.0
	b	23	17.7	16.8	16.4	16.0	15.9	15.5	15.5
	c	30	16.8	16.0	14.5	14.0	14.0	13.0	13.0
JULY	d	7	19.4	19.4	19.4	[19.4	14.5]	13.2	13.0
	e	14	20.7	19.0	17.7	17.0	15.9	13.5	13.5
	f	21	20.8	20.6	20.5	[20.4	17.0]	16.5	14.0
	g	28	23.5	23.0	22.5	[22.0	19.2	16.5]	14.5
AUGUST	g	4	24.5	24.2	24.2	[22.3	18.5	15.7]	14.8
	i	11	23.6	23.5	23.0	[22.5	20.0	16.0]	17.5
	j	18	21.5	20.5	19.8	19.0	18.5	17.6	16.5
	k	25	19.4	19.5	19.3	18.5	18.3	16.0	16.5
SEPTEMBER	l	1	15.2	15.2	15.2	15.2	15.0	14.8	14.8
	m	8	14.6	14.6	14.2	14.0	13.6	13.6	13.8
	n	15	11.0	10.8	10.8	10.9	10.9	10.9	10.9
	o	25	9.0	8.6	8.6	8.6	8.6	8.7	9.2
OCTOBER	p	1	9.8	9.4	9.3	9.3	9.2	9.2	9.2
	q	17	8.6	8.0	8.1	8.0	8.0	8.0	8.0
NOVEMBER	r	1	6.2	5.6	5.5	5.5	5.5	5.5	5.7
DECEMBER	s	20	1.1	0.5	1.7	2.3	3.0	3.4	4.1
FEBRUARY	t	6	0.8	0.8	1.5	3.0	3.5	3.8	4.0
MARCH	u	14	1.3	2.2	3.1	3.8	4.2	5.0	5.0
MAY	v	12	12.2	12.0	12.0	12.0	12.0	12.0	12.0
	w	26	16.2	15.5	15.0	14.1	13.5	13.2	13.0

-Thermoclinesin Brackets
-Water Temperatures in °C.

Ice cover measurements are given by Figure 6, page 44. Freezeup took place during the week of November 7-13. As the snow cover decreased from a maximum of 35.6 centimeters on February 6 to 15.3 centimeters on March 14, the thickness of the ice increased markedly. At the same time light penetration increased, which suggests that snow cover limits light penetration to a greater extent than does ice cover. The fact that the ice in Muir Lake remained remarkably clear no doubt contributed greatly to the deep light penetration.

The Secchi disc water transparency recordings (Figure 6, page 44) exhibit a seasonal pattern. First, an increase in transparency took place due to a decrease in turbidity after the settling of suspended sediment following spring turnover. Then, from mid July to September 1, a steady decrease occurred due to the effect of increased wind action and, to a lesser extent, phytoplankton accumulation. After September 1 an increase in transparency , likely due to the decomposition of the accumulated phytoplankton (Cyanophytes), occurred. Finally, a slight decrease was observed when fall turnover took place.

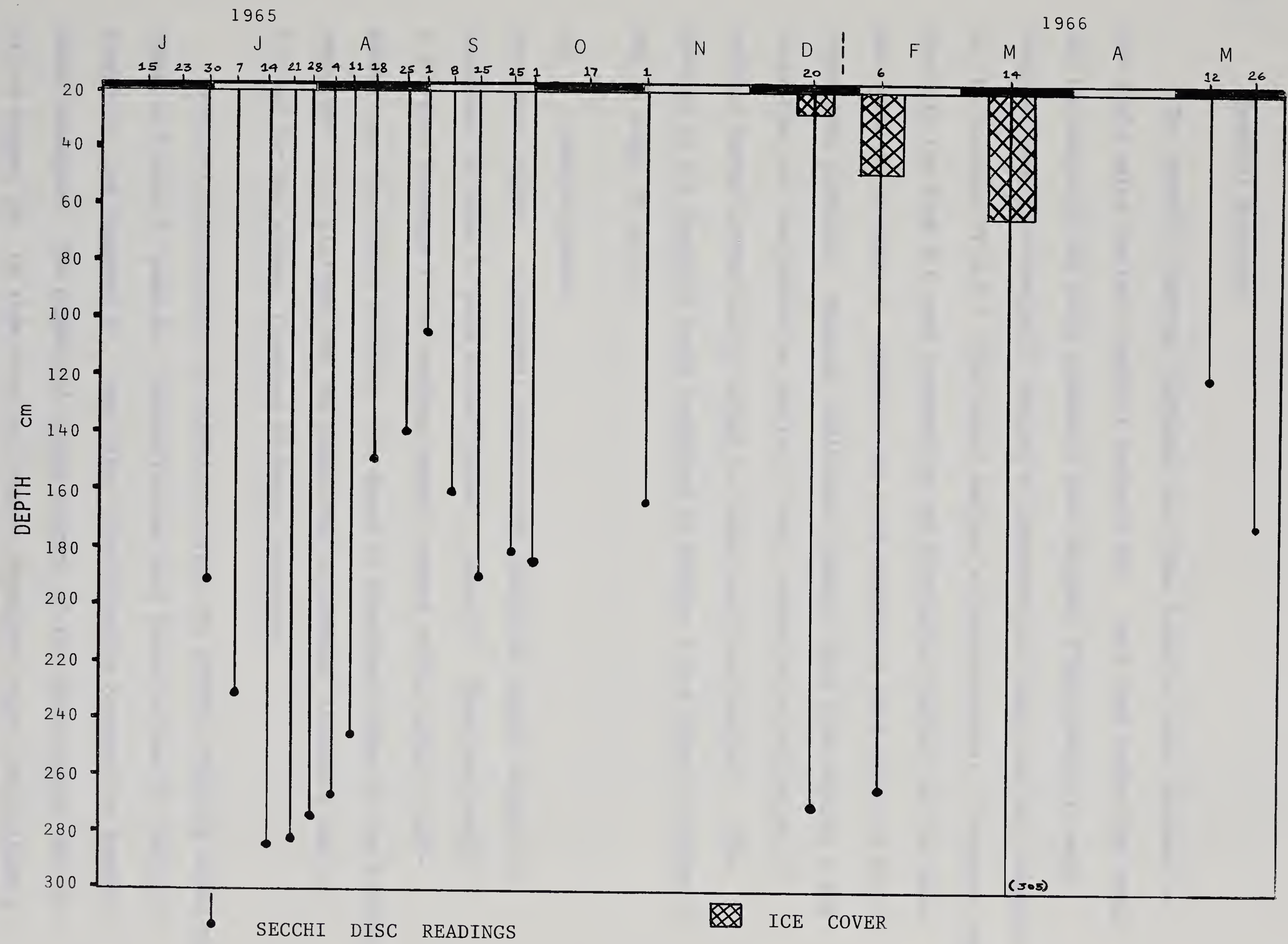
Plate 4. Muir Lake as seen across station 1 from the west-south-west showing freezeup on November 11, 1965. Note that only the middle of the lake is ice-free.

Plate 5. Muir Lake as seen from the west-south-west, looking across station 1, showing the ice cover on May 1, 1966. Note that only 3 to 4 meters from the lake margin is ice-free.

4.

5.

Figure 6. Seasonal secchi disc water transparency and ice cover measurements at station 1 in Muir Lake for the period June 1965 To May 1966.


1965
1966
J J A S O N D F M A M
15 23 30 7 14 21 28 4 11 18 25 1 8 15 25 1 17 1 20 6 14 12 26
DEPTH cm
20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
(305)
SECCHI DISC READINGS
ICE COVER

2. Chemical Features

The chemical features discussed are those based on data obtained in the field using the Hach Chemical Analysis Kit. Data from tests that could not be made with the above apparatus (see Methods: Field-Chemical) were obtained from the Provincial Analyst's Laboratory and when used are indicated by the notation "P.A.D." (Provincial Analyst's Determinations). Selected tests run with the Hach Kit were repeated by the Provincial Analyst and his data are included in Table 7. However, the more consistent data from the field tests were prefered. Wherever additional chemical data from station 2 are given they are designated as station 2 data, otherwise no indication of station number automatically refers to those data from station 1. The results of all chemical tests conducted at station 1 are given in Tables 6 and 7, pages 46 and 51.

(i) Dissolved Gases

Dissolved Oxygen: A seasonal cycle of the dissolved oxygen content is indicated by Table 6, page 46 and Figure 7, page 47. There was roughly a 3.5-fold increase in the maximum oxygen content of the water in mid-summer over the winter minimum. The range of dissolved oxygen of the surface water was 7.7 - 11.0 ppm for the period May to November inclusive and 3.1-9.0 ppm for the winter, December to March inclusive.

Vertical distributions of dissolved oxygen for several sampling dates are given in Figure 8, page 48. Stratification took place on June 15, July 21, August 25, and December 20. Very minor stratification occurred on several other occasions. The dissolved oxygen content of the bottom water fell to nil on August 25. On that date epilimnetic dissolved oxygen was uniformly distributed while the hypolimnetic dissolved oxygen

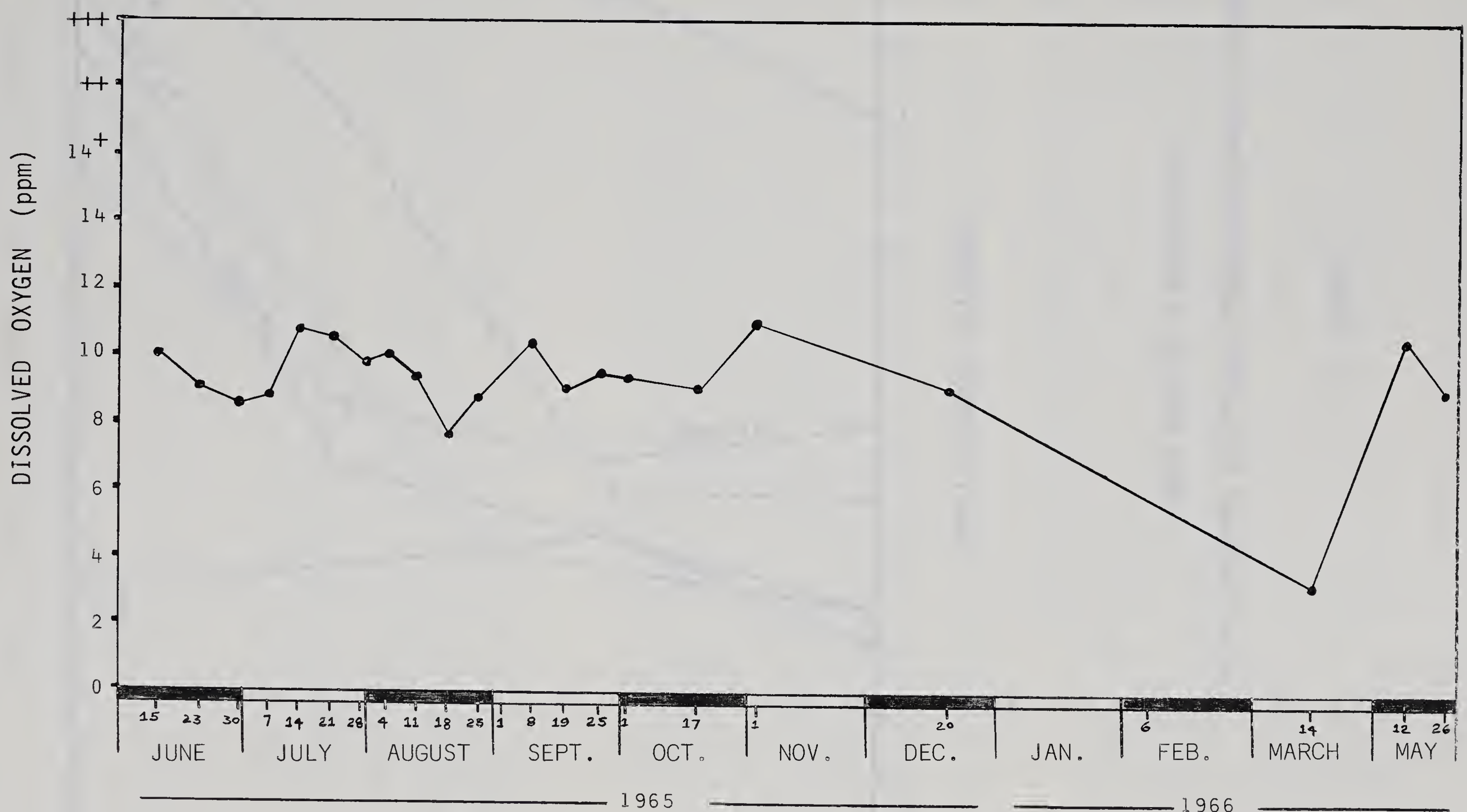
TABLE 6

Dissolved Gases And Hydrogen-Ion Concentrations At Station 1 On Muir Lake For The Period June 8, 1965 to May 26, 1966

		JUNE				JULY				AUGUST					SEPT			OCT		NOV	DEC	FEB	MAR	MAY	
	DEPTH	8	15	23	30	7	14	21	28	4	11	18	25	1	8	15	25	1	17	1	20	6	14	12	26
OXYGEN ppm	0 M	-	10.5	9.3	8.6	8.8	10.0	10.5	9.8	10.0	9.5	7.7	8.8	-	10.4	9.0	9.6	9.4	9.0	11.0	9.0	-	3.1	10.5	9.0
	1 M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 M	-	-	-	8.2	9.0	10.0	9.4	9.8	10.5	9.5	8.2	8.8	-	10.4	9.0	9.6	-	-	9.5	7.8	-	1.2	-	9.5
	3 M	-	9.5	8.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4 M	-	-	7.3	-	-	10.0	8.4	7.5	8.3	7.2	7.4	3.2	-	7.8	9.0	9.6	10.6	-	-	0.65	-	0.5	11.0	10.0
	5 M	-	-	-	5.5	6.3	-	-	-	-	-	-	0.8	-	-	-	-	-	-	10.0	0.35	-	-	-	-
	6 M	-	1.1	-	-	-	5.3	2.1	6.0	5.4	3.0	3.9	0.0	-	-	9.0	9.6	-	-	-	-	-	-	-	-
CARBON DIOXIDE ppm	0 M	2.0	8.0	12.0	8.0	6.3	10.0	8.0	4.0	0.0	6.0	16.0	16.0	-	12.0	20.0	36.0	28.0	-	30.0	44.0	-	48.0	24.0	12.0
	1 M	4.0	-	14.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 M	4.0	8.0	16.0	18.0	14.0	12.0	14.0	10.0	8.0	6.0	20.0	22.0	-	20.0	22.0	38.0	-	-	32.0	40.0	-	48.0	-	-
	3 M	4.0	8.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4 M	4.0	-	17.0	-	-	14.0	16.0	14.0	16.0	40.0	56.0	32.0	-	28.0	26.0	-	20.0	-	-	32.0	-	48.0	-	25.0
	5 M	4.0	8.0	-	28.0	26.0	20.0	40.0	28.0	20.0	40.0	40.0	52.0	-	-	30.0	40.0	-	-	36.0	40.0	-	-	-	-
pH	0 M	8.3	8.4	8.4	8.3	8.6	8.4	8.8	8.6	8.7	8.8	8.5	8.6	8.5	8.6	8.6	8.4	8.4	8.5	8.6	8.6	8.4	8.5	8.6	8.6
	6 M	-	-	-	7.5	7.4	7.8	7.6	7.8	8.4	8.1	7.6	7.6	-	-	8.5	-	8.4	8.5	-	8.6	-	-	-	8.6
TIME OF SAMPLING hrs		1300	1300	1100	1100	1000	0930	1330	1200	1200	1100	1400	1200	1200	0930	1300	1130	1415	1600	1415	1045	1230	1300	1200	0930

Figure 7.

Seasonal Distribution of Dissolved Oxygen From The Surface Water At Station 1
In Muir Lake



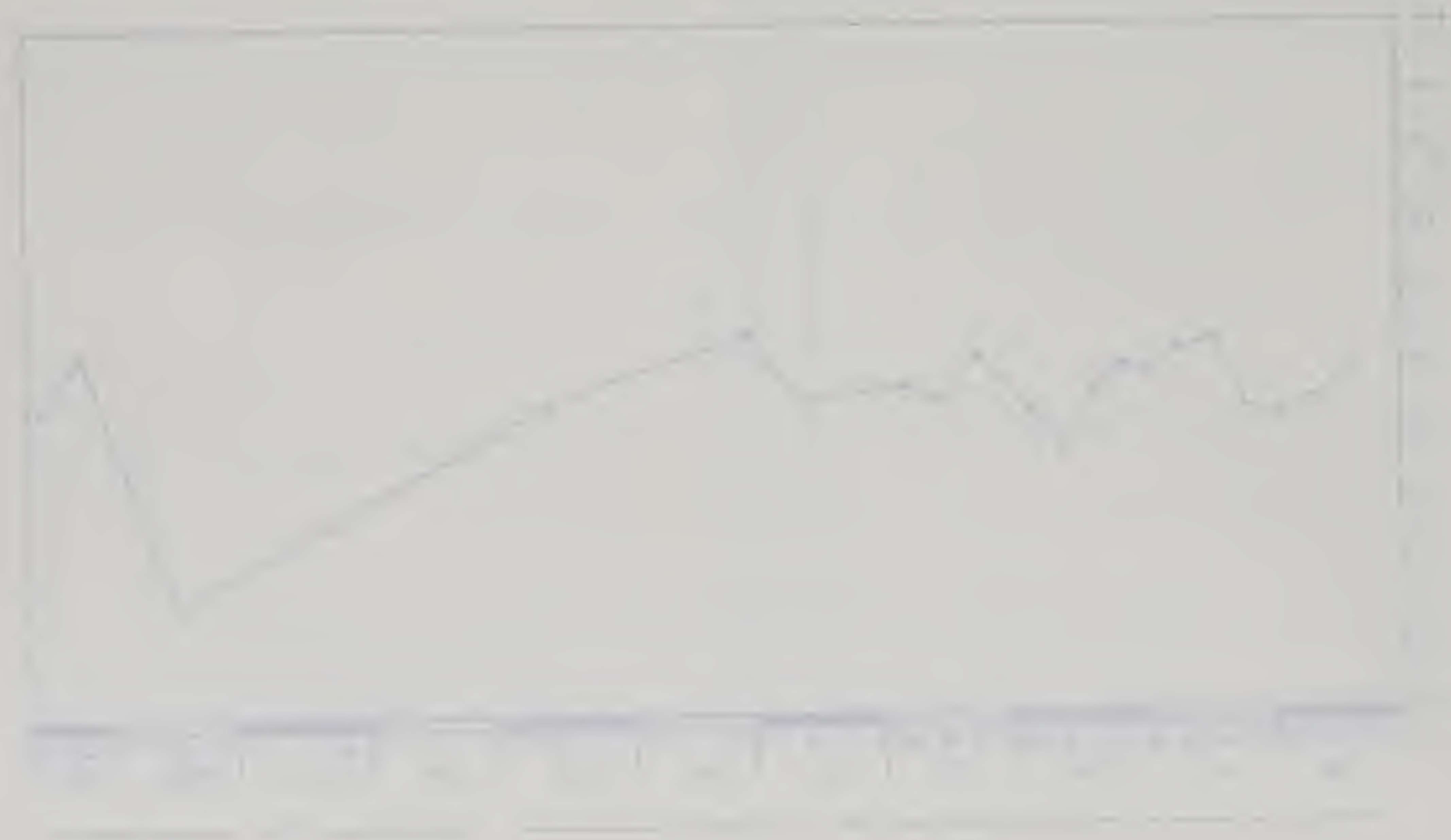
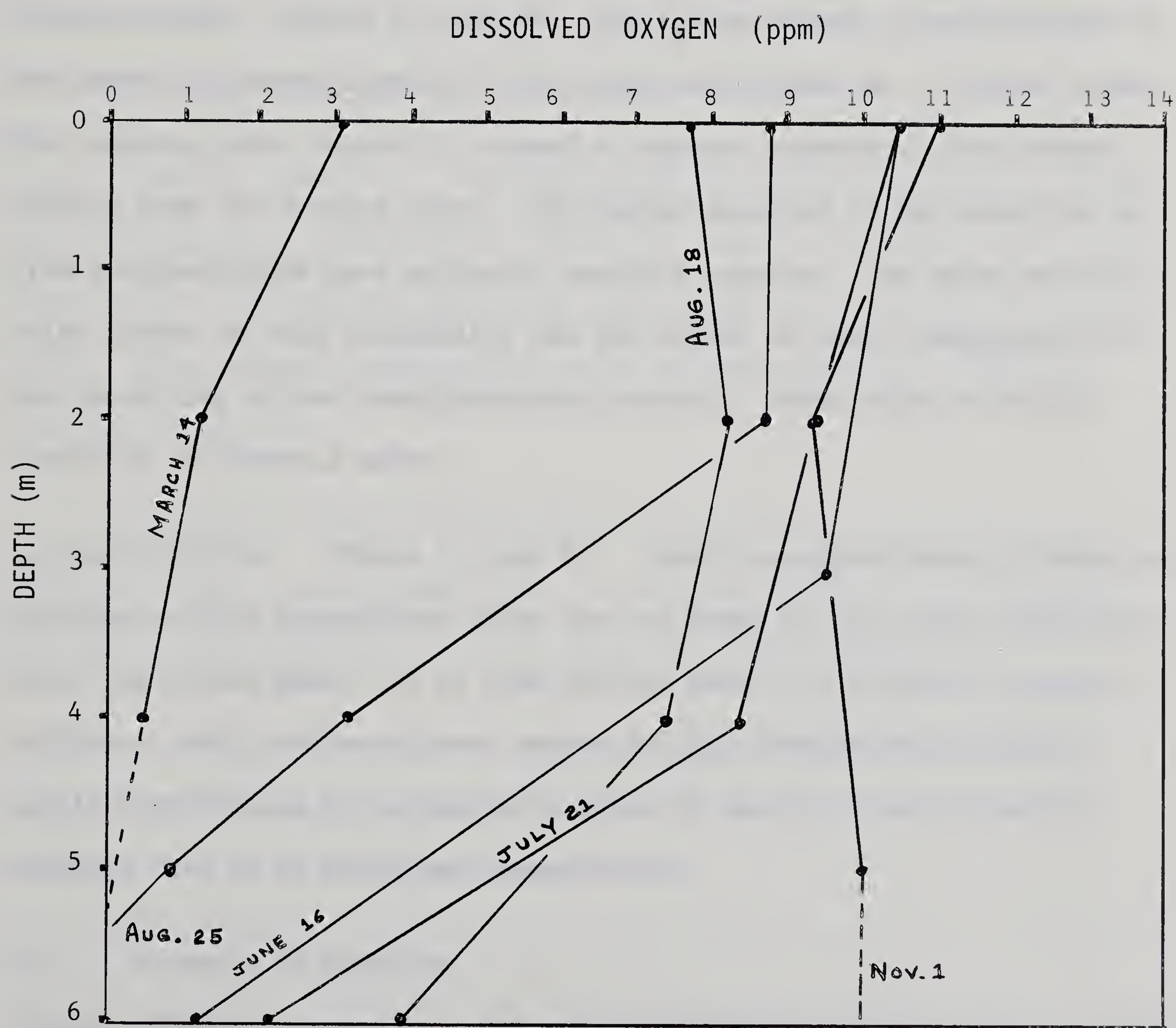


Figure 8.

Vertical Dissolved Oxygen Series For Selected Dates

At Station 1 On Muir Lake



declined gradually toward the bottom where no oxygen was found. The curve for August 25 (maximum stratification) is of the clinograde type (high concentration of oxygen in epilimnion, little or no oxygen in the hypolimnion). Most other curves tended to be closer to an orthograde type (more or less uniform distribution of dissolved oxygen from surface to bottom). The formation of vertical oxygen concentration curves closely resembling the classical orthograde type is held as additional evidence that Muir Lake is a relatively unproductive body of water.

Carbon-Dioxide: (Table 6, page 46) During the summer, stratification in the amount of carbon-dioxide in the water was evident to a limited extent. One sampling date (August 4), showed a complete absence of free carbon-dioxide from the surface water. The method exployed in the detection of free carbon-dioxide gave extremely variable results. The major contributing factor to this variability was the effect of water temperature on the solubility of the phenolphthalein crystals, these being virtually insoluble in ice-cold water.

Hydrogen-Sulfide: (Table 7, page 51) Small concentrations of dissolved hydrogen sulfide accumulated under the ice cover in the water immediately above the bottom muds. At no time did the amount of dissolved hydrogen sulfide in Muir Lake water ever exceed 2.0 ppm (bottom water-winter). Little anaerobiosis is an obvious feature of this lake and is further evidence that it is relatively unproductive.

(ii) Minerals in Solution

Silica: (Table 7, page 51) The silica concentrations were found to vary seasonally and vertically. The vertical distribution of silica

frequently showed the highest concentration in the bottom waters.

The seasonal distribution of surface water silica showed a range of variation from 0.23 - 5.60 ppm with a mean of 2.18 ppm. A concentration which ranged from 1.00 - 1.64 ppm was found throughout June and early July. The concentration then dropped to the lowest reading of the year by July 21 (0.23 ppm). A small increase in concentration of silica was then observed on August 4, followed by a stable concentration for the remainder of the summer. Autumnal overturn added roughly 2.0 ppm of silica to the average summer concentration. The highest reading of 5.60 ppm was found beneath the cover of ice and snow on March 14.

Iron: (Table 7, page 51) The slight stratification of dissolved oxygen that developed was sufficient to raise the content of ferrous iron in the bottom waters appreciably beyond the level found at the surface during mid-summer. The highest concentration recorded for the bottom water was 1.50 ppm on July 28.

The seasonal range of surface soluble iron was found to be 0.001-0.200 ppm with a mean of 0.063 ppm. The highest reading of 0.200 ppm was recorded on February 6, at the height of winter stagnation.

Sulfates: (Table 7, page 51) One of the most striking characteristic features of the water chemistry of Muir Lake was the low content of sulfates. The highest recorded concentration for the period of study was 25 ppm (June 23, 1965) and the lowest concentration was 5.0 (May 26, 1966) The mean of twenty-four surface water samples was 10.5 ppm.

TABLE 7

Chemical Data From Station 1 At Muir Lake For The

Period June 8, 1965 to May 26, 1966

All Readings In ppm		JUNE B	JUNE 15	JUNE 23	JUNE 30	JULY 7	JULY 14	JULY 21	JULY 28	AUGUST 4	AUGUST 11	AUGUST 18	AUGUST 25	SEPT 1	SEPT 8	SEPT 15	SEPT 25	OCT 1	OCT 17	NOV 1	DEC 20	FEB 6	MAR 14	MAY 12	MAY 26
ALKALINITY	Phenol.	-	10	10	20	15	20	15	20	20	20	15	20	20	40	30	10	5	10	5	0	5	0	30	20
	Carbon.	-	20	20	20	40	30	40	30	40	40	30	40	40	80	60	20	10	20	10	0	10	0	60	40
	Bicarb.	-	140	120	90	65	110	90	110	90	100	110	100	110	70	100	140	145	150	105	210	250	220	120	130
	Total	150	160	140	110	105	140	130	140	130	140	140	140	150	150	160	160	155	170	115	210	260	220	180	170
	P.A.D.	-	135	135	135	100	125	125	-	125	-	140	-	60	125	125	145	-	165	165	175	180	220	-	-
CHLORIDES	HACH	5	-	-	-	-	10	10	5	5	15	7.5	10	5	7.5	5.5	7.5	5	7.5	5	7.5	7.5	5	7.5	7.5
	P.A.D.	-	Nil	-	-	Nil	-	Nil	-	Nil	-	Nil	-	Nil	Nil	-	Nil	-	5.4	Nil	Nil	2.0	Nil	-	-
HARDNESS	Calcium	70	100	20	90	60	70	70	70	100	60	20	15	60	60	75	75	9.5	80	90	98	60	105	90	110
	Total	130	125	120	130	110	120	130	105	180	120	120	130	120	110	130	130	130	140	145	170	160	180	140	155
	P.A.D.	-	210	155	135	115	160	210	180	100	100	165	270	195	125	125	145	-	130	250	170	170	175	-	-
HYDROGEN SULPHIDE		Nil	Nil	Nil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B=0	S=0 B=2	4M=2	-	-
SULPHATE	HACH	11	7	25	13	8	7.5	6.5	12	10	16	14	10	12	18	9	7	8	8	8	11	10	7.5	8	5
	P.A.D.	-	39	-	24	Nil	-	26	-	12	-	22	-	26	59	-	29	-	9.0	48	19.5	-	Trace	-	-
T.D.S.	P.A.D.	-	226	212	218	220	250	216	216	182	210	222	288	206	298	196	238	-	204	304	250	222	268	242	-
IGNITION LOSS	P.A.D.	-	72	-	100	160	80	100	114	78	144	104	130	126	124	134	106	-	72	122	126	112	130	-	-
ORGANIC MATTER	P.A.D.	-	23	50	24	110	10	173	35	34	100	42.4	-	100	70	79	19	-	14	11	51	37.2	-	-	-
CALCIUM	P.A.D.	-	28.8	-	28.8	-	-	26	26	24.4	21.6	30	35.2	38	28	28.4	33.6	-	36.0	42	40	38.4	46.4	-	-
MAGNESIUM	P.A.D.	-	-	-	-	-	-	-	-	9.4	-	21.9	44.2	24.3	13.3	-	14.8	-	9.7	35.2	17	17.8	14.3	-	-
SODIUM	P.A.D.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.5	Trace	11.9	-	-
POTASSIUM	P.A.D.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.2	10.0	15	-	-
CHLORINE		Trace	-	-	-	-	-	-	-	-	.01	-	.01	.04	-	-	-	-	-	-	-	-	-	-	-
CHROMATE		.13	-	-	-	-	-	-	-	-	.15	-	.01	-	.28	.23	.17	.09	.24	.32	.23	.26	.2	.13	.14
COPPER		.14	-	-	-	-	.18	-	-	-	.14	-	.65	.12	.10	.30	.18	.07	.15	.26	.22	.18	.16	Trace	.16
IRON		.05	.04	.03	Nil	Nil	Nil	.004	.35	Nil	.08	.002	.08	.09	.05	.08	.01	.04	.01	.02	.08	.20	.04	.08	.05
MANGANESE		.26	-	.15	-	-	1.1	Nil	.12	.65	.25	1.05	.20	.40	.35	.50	1.50	.20	.30	.60	.50	1.8	.60	.35	Trace
NITRATE N		1.2	.55	Nil	-	Nil	1.8	-	Nil	-	-	Nil	Nil	Nil	Nil	-	Nil	-	.30	Nil	Nil	-	-	Nil	-
NITRITE N		.002	.004	Nil	-	Nil	.005	-	Nil	-	-	Nil	Nil	Nil	Nil	-	Nil	-	Trace	Nil	Nil	Nil	.02	Trace	.02
PHOSPHATE	HACH ORTHO	.08	.04	.38	-	-	1.68	S=.2 B=.4	.17	.24	.05	.15	.05	.10	.10	.10	.02	.18	.09	.24	.12	.08	.14	Nil	.30
	P.A.D. ORTHO	-	-	-	-	-	-	-	-	-	-	-	-	.28	.80	1.0	.85	-	2.98	3.75	-	1.78	.24	-	-
	P.A.D. TOTAL	.08	-	-	.15	.80	-	.5	2.1	.22	1.3	.95	.55	1.18	1.38	-	.95	-	-	-	.6	-	1.0	.33	-
SILICA		.57	1.02	1.0	1.18	1.84	.28	.23	1.25	3.8	1.24	2.25	2.20	2.5	2.5	2.9	2.88	4.4	3.6	2.8	2.2	3.2	5.6	1.62	1.45

Explanation of Abbreviations: P.A.D.= Provincial Analyst's Data
S= Surface
B= Bottom

Phenol.= Phenolphthalein
Carbon.= Carbonate
Bicarb.= Bicarbonate

Chlorides: (Table 7, page 51) The chloride ion concentration remained relatively uniform throughout the study period. The range of concentration of chlorides as determined from surface waters was 5.0-15.0 ppm with a mean of 7.25 ppm.

Nitrate-Nitrogen: (Table 7, page 51) The range of nitrate-nitrogen concentrations for the study period was 0.0-1.8 ppm with a mean of 0.256 ppm for fifteen samples. A seasonal cycle of nitrates was found. When measurements of surface nitrates were first taken on June 8, 1965, a concentration of 1.198 ppm was detected. This concentration then declined steadily until no measurable nitrates were found. This occurred on June 23. July 14 showed a sharp increase to the maximum recorded level of 1.8 ppm. The concentration of nitrate-nitrogen then dropped to nil one week later. An increase in nitrates was observed in October and was related to the autumnal overturn where surface waters were recharged with hypolimnetic or bottom nitrates.

Nitrite-Nitrogen: (Table 7, page 51) The range of nitrite-nitrogen concentrations detected was 0.0-0.016 ppm with a mean of 0.0024 ppm for 19 samples. The highest concentration was obtained following breakup in spring and the months following freezeup in fall.

Phosphorus: (Table 7, page 51) Ortho-phosphate phosphorus (soluble inorganic phosphorus) determinations were made with the Hach Chemical kit. The resulting measurements tended to be higher than those of other workers using more refined analytical techniques (Pearsall 1932;Tucker 1957). These results are held as relative and provide useful information on this basis. The results were used as a comparative index of phosphorus in the

two bodies of water studied. Data of total phosphates were obtained from the Provincial Analyst.

The surface water ortho-phosphate phosphorus range was 0.001 - 1.68 ppm. A reading of 1.68 ppm was obtained on July 14. The second highest reading of 0.38 ppm was obtained on June 23. The yearly mean concentration of ortho-phosphate phosphorus was 0.045 ppm. Variations in total surface phosphates ranged from 0.05 - 2.10 ppm throughout the study period. Higher readings of ortho-phosphate phosphorus were obtained from bottom waters than from surface waters.

Trace Elements: (Table 7, page 51) The trace elements copper, chromate, and manganese demonstrated relatively uniform concentrations throughout the study period. The means for these three trace elements were 2.00, 0.182, and 0.54 ppm respectively.

Cations: (Table 7, page 51) The mean concentration of the cations calcium, magnesium, sodium and potassium were 33.0, 20.0, 9.4, and 12.0 ppm respectively. The concentration ranges of the cations were 21.6-42.0, 9.4-44.2, trace-16.5, and 9.25-15.0 ppm respectively. Generally speaking, all four cations increased in concentration throughout the summer and winter and decreased markedly during spring runoff.

(iii) Other Substances in Solution

Total Dissolved Substances (T.D.S.) (Table 7, page 51) The total dissolved substances ranged in value from 182-304 ppm with a mean of 233 ppm. A slight seasonal cycle in T.D.S. was found during the study. The concentration tended to increase slightly as a result of summer

evaporation then increase rapidly when freezeup took place. The T.D.S. increased as did the ice thickness. Finally, a drop in T.D.S. occurred during the dilution accompanying spring thaw.

Organic Matter: (Table 7, page 51) The concentrations of organic matter in the water showed a considerable variation within the range of 10-173 ppm with a mean of 55 ppm. The low reading of 10 ppm was recorded on July 14 at a time when many phytoplankton species (mostly Chlorophyta) increased in numbers. The high readings one week before and one week after the minimum readings were accompanied by low numbers of these phytoplankters.

Hardness: (Table 7, page 51) According to the U.S. Geological Survey's classification of waters based on hardness, Muir Lake water is "hard". The mean total hardness of Muir Lake water, in terms of amount of calcium carbonate present, was 134 ppm and is close to the Geological Survey's lower limit of the range for "hard" waters (121-180 ppm).

The seasonal range of total hardness was found to be 105-180 ppm. High readings were obtained in winter with a sharp decrease following the dilution effect of spring thaw. The sudden increase in total hardness of the surface water on August 4 was accompanied by a depletion of free carbon dioxide. On this date, the highest number of *Anabaena circinalis* cells were recorded.

Alkalinity: (Table 7, page 51) The mean alkalinity for the study period was 155 ppm (36 ppm carbonate alkalinity, 119 ppm bicarbonate alkalinity). Little seasonal fluctuation occurred during the ice-free

period, but a rapid increase in alkalinity occurred during the winter. A decrease from 220 ppm total alkalinity to 180 ppm from March 14 to May 12 took place due to the dilution effect of ice melt-water.

Local variations in the concentrations of bicarbonate and carbonate alkalinities occurred during the ice-free period. On June 30, a decrease from 120 to 70 ppm in bicarbonate alkalinity occurred. At the same time the carbonate alkalinity increased from 20 to 40 ppm and the total alkalinity decreased from 140 to 110 ppm. During this change, two factors were found to operate. Firstly, the decrease in total alkalinity was caused by the dilution effect of the heavy rainfall in late June. Secondly, the drop in the bicarbonate alkalinity with the rise in the carbonate alkalinity was caused by the reduction in free carbon-dioxide by the phytoplankters *Coelastrum microporum* and *Anabaena flos-aquae*. These two species of algae were presumed to utilize half-bound carbon-dioxide (bicarbonates) as their carbon-dioxide supply. Both species reached peak numbers on this date. A similar condition was found on September 8. At this time the bicarbonate alkalinity decreased from 110 to 70 ppm while the carbonate alkalinity rose to 80 from 40 ppm. The total alkalinity, however, remained unchanged. The increase in the number of certain green algae such as *Scenedesmus spp.*, *Pediastrum spp.*, and *Ankistrodesmus falcatus* was likely responsible for this decrease in bicarbonate alkalinity.

Hydrogen-Ion Concentration: (Table 6, page 46) The hydrogen-ion concentration ranged from a low of 8.30 to a high of 8.85. The average pH for the entire period of study was 8.53 for the surface water. Determinations made on bottom waters resulted in an average pH of 8.04

with a range of 7.45-8.65. As a result of the presence of free carbon-dioxide in the surface water on all but one sampling date, the pH remained relatively uniform throughout the study.

(iv) Chemistry of the Bottom Sediments and Ice.

Bottom Sediments: (Table 8, page 57) Chemical analyses were conducted on the bottom sediments of station 1 and station 2 during the winter. These data reflect the nature of the water chemistry of the lake with low conductivity and an imbalance in the available nitrogen and phosphorus.

Ice: Table 9, page 57 shows the results of chemical analyses made on ice melt-water. An attempt was made to obtain the February 6 sample at a depth that was ice-free on December 20. This accounts for the lower reading of T.D.S. and ignition loss on February 6. The ortho-phosphate phosphorus concentrations were found to be fairly high, being 0.40 and 0.44 ppm respectively on the two sampling dates. It is interesting to point out that the ortho-phosphate phosphorus concentration of the water beneath the ice was 0.12 and 0.06 ppm on December 20 and February 6 respectively. Ice tends to concentrate the inorganic phosphorus which likely makes this nutrient a limiting chemical factor during the winter period.

TABLE 8

Chemical Analysis Of The Bottom Sediments In Muir Lake From Samples Collected During The Winter (December 20 and February 5)

Sample	lbs/acre nutrients N	P	K	pH	Cond. (mmho)	Sulfates	Free Lime
Stn. 1	5	Nil	600+	6.9	3.2	High	Low
Stn. 2	Nil	17	600+	7.2	1.5	Med.	Low

TABLE 9

Chemical Analysis Of Muir Lake Ice Water (P.A.D.)

Station 1

Date	T.D.S. (ppm)	Ignition Loss (ppm)	Ortho-Phosphate Phosphorus (ppm)
Dec. 20	54	32	0.40
Feb. 6	26	8	0.44

3. Biotic Features

(i) Aquatic Macrophytes

Floating Macrophytes: Of the plants included in this category, only one *(Lemna minor)* was wholly floating. Those macrophytes with "floating" leaves make up the remainder of this group. The following table gives the species present and their relative seasonal abundance.

TABLE 10

Floating Aquatic Macrophytes In Muir Lake And Their Relative Abundance

Species	Relative Abundance
Lemna minor	Rare
Nuphar variegatum	Abundant
Potamogeton gramineus	Occasional
Polygonum amphibium var. stipulaceum	Rare
Sagittaria cuneata	Occasional

Figure 9, page 59 shows the maximum extent of the zone of floating macrophytes. The yellow pond lily, *Nuphar variegatum*, was the most abundant floating macrophyte and the dominant of all the aquatics in Muir Lake. *Lemna minor* and *Polygonum amphibium* var. *stipulaceum* were confined to small, shallow areas within the lake. Both *Potamogeton gramineus* and *Sagittaria cuneata* were found near the island and mixed with shallow water macrophytes in the south bay of the lake.

Figure 9. Map of Muir Lake showing the maximum extent of the Zone of Floating Aquatic Macrophytes.


LEGEND
Macrophytes wholly floating or with floating leaves
0.1 Mile
N
MUIR LAKE

Plate 6. Floating aquatic macrophytes in Muir Lake in August, 1965. Mostly *Nuphar variegatum*.

Plate 7. Emergent *Equisetum fluviatile* in Muir Lake in August, 1965.

6.

7.

Emergent Macrophytes: Many species of emergent aquatic plants were found along the shallow margin of the lake. These species with their relative abundance are listed in Table 11.

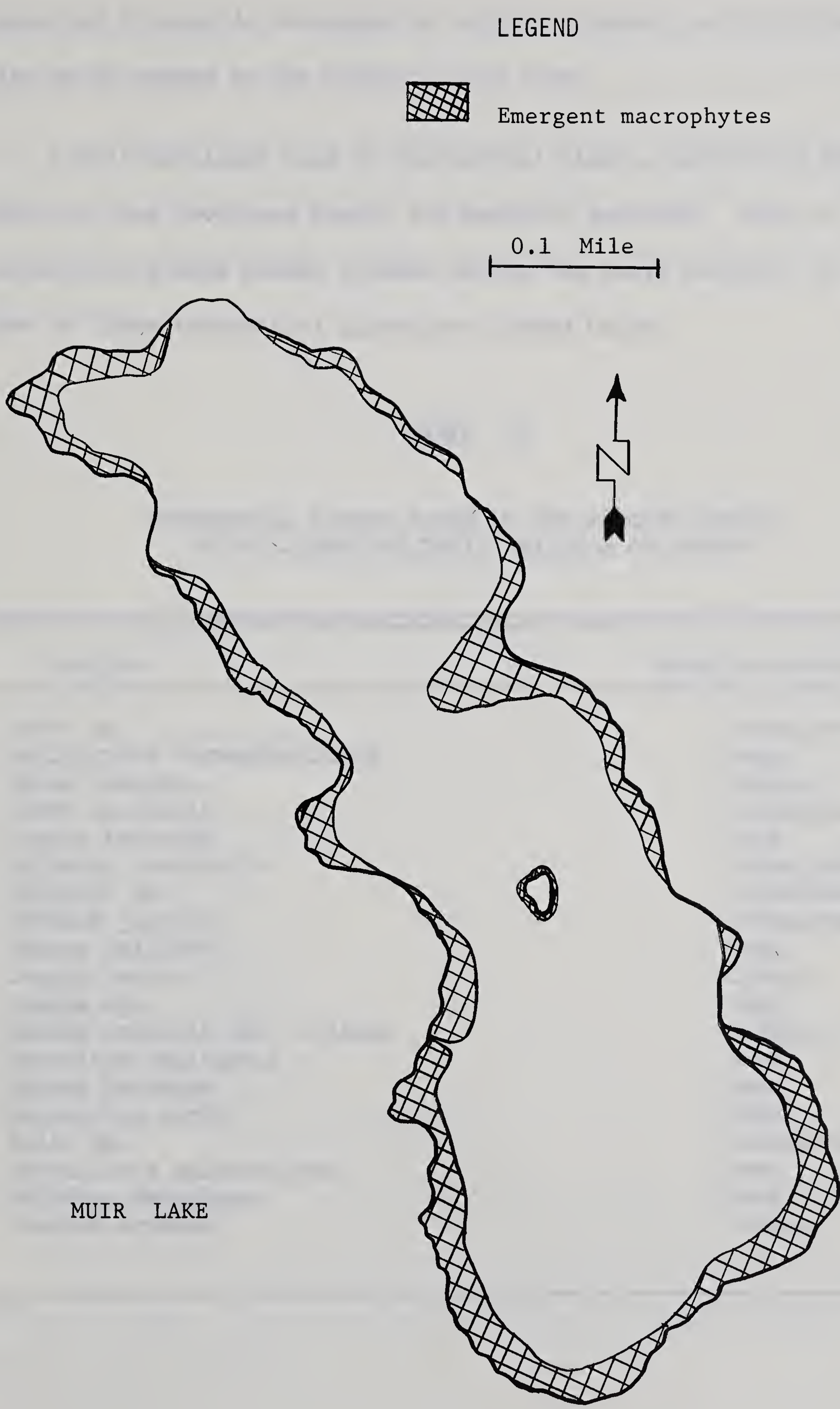
TABLE 11

Emergent Aquatic Macrophytes In Muir Lake And Their Relative Abundance

Species	Relative Abundance
Beckmannia syzigachne	Rare
Calamagrostis canadensis	Common
Calla palustris	Rare
Equisetum fluviatile	Common
Eleocharis palustris	Occasional
Glyceria grandis	Occasional
Phalaris arundinacea	Common
Phragmites communis	Rare
Scirpus validus	Abundant
Sparganium eurycarpum	Common
Sium suave	Rare
Typha latifolia	Abundant

The extent of the zone of emergent macrophytes is shown by Figure 10, page 62. *Typha latifolia* and *Scirpus validus* were the codominants (both abundant and controlling the emergent aquatic community) and formed a more or less continuous band surrounding the entire lake. On the lakeward side of the band of cattails and bulrushes, and mixed with it, grew *Sparganium eurycarpum* and *Eleocharis palustris* while on the shoreward side of the band grew *Phalaris arundinacea*.

Figure 10. Map of Muir Lake showing the maximum extent of the Zone of Emergent Aquatic Macrophytes.


LEGEND
Emergent macrophytes
0.1 Mile
N
MUIR LAKE

Equisetum fluviatile developed an extensive growth on the mid-west shoreline which spread to the middle of the lake.

A well developed band of terrestrial plants, preferring moist habitats, was developed beyond the emergent aquatics. Many of these terrestrial plants became flooded during the heavy rainfall in June. Some of these terrestrial plants are listed below.

TABLE 12

Terrestrial Plants Found On The Flooded Margin Of Muir Lake And Their Relative Abundance

Species	Relative Abundance
Aster sp.	Occasional
Callitriche hermaphroditica	Rare
Carex rostrata	Common
Carex aquatilis	Occasional
Crepis tectorum	Rare
Erigeron canadensis	Occasional
Erigeron sp.	Occasional
Hordeum jubatum	Occasional
Juncus balticus	Rare
Juncus tenuis	Common
Juncus sp.	Rare
Mentha arvensis var. villosa	Common
Petasites sagittatus	Rare
Phleum pratense	Rare
Ranunculus acris	Rare
Salix sp.	Occasional
Scutellaria galericulata	Rare
Solidago decumbens	Rare
Sonchus arvense	Common

Submersed Macrophytes: Figure 11, page 65 shows the zones of occasional and abundant submersed aquatic macrophytes. The area of occasional macrophytic growth was dominated by *Potamogeton zosteriformis* with the occasional plant of *Potamogeton praelongus* and *Ceratophyllum demersum.* The zone of abundant submersed aquatics was composed of the plants given in the table below.

TABLE 13

Submersed Aquatic Plants In Muir Lake And
Their Relative Abundance

Species	Relative Abundance
Ceratophyllum demersum	Common
Chara sp.	Abundant
Hippuris vulgaris	Common
Myriophyllum exalbescens	Common
Myriophyllum verticellatum	Occasional
Najas flexilis	Abundant
Potamogeton filiformis	Rare
Potamogeton freisii	Occasional
Potamogeton gramineus	Rare
Potamogeton pectinatus	Common
Potamogeton prelongus	Rare
Potamogeton pusillus	Occasional
Potamogeton richardsonii	Rare
Ranunculus aquatilis	Rare
Utricularia vulgaris var. americana	Rare

Meadows of the alga *Chara* and the macrophyte *Najas flexilis* developed within this zone. These two plants were found in equal numbers and both were extremely abundant.

Figure 11. Map of Muir Lake showing the Zone of Abundant Submersed Aquatic Macrophytes and the Zone of Occasional Submersed Aquatic Macrophytes.


LEGEND
Abundant submersed macrophytes
Occasional submersed macrophytes
0.1 Mile
MUIR LAKE

A seasonal succession of the species of *Potamogeton* was observed in regard to time of flowering and fruiting. The chronological order of the species was: *Potamogeton richardsonii* and *P. filiformis* (late July); *P. pectinatus* and *P. freisii* (early August); *P. zosteriformis* (mid August); *P. gramineus* and *P. pusillus* (early September). *P. praelongus* was the last to flower and set fruit in mid September.

One of the factors that contributed largely to the presence of the abundant aquatic macrophytic flora in Muir Lake was light penetration. Low turbidity allowed light penetration to a large portion of the bottom. Consequently, the entire bottom, with the exception of a small area near station 1, was inhabited by some aquatic macrophyte.

(ii) Benthic and Aufwuchs Algae

Due to deep light penetration, a well developed benthic* (epipelic) algal community was produced. Also, because of large numbers of different emergent and submersed aquatic macrophytes in Muir Lake, a well developed Aufwuchs** community was produced. Algal species from both of these communities (with their relative abundance) are listed on pages 67, 68, 69, and 70.

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* benthic algae= those algae found on the bottom sediments which are equated to epipelic algae.

** Aufwuchs algae= used here as meaning those algae attached to or free-living on a submersed substrate, usually aquatic macrophytes. Not to be confused with "periphytonic" algae which refers only to those algae that are sessile and excludes those species which are free-living but which are found clustered on the same submersed substrate as are those forms directly attached to it.

Muir Lake: Benthic and Aufwuchs Algae With Notes On Their Relative Abundance And Substrate

Division Chlorophyta

Class Chlorophyceae

Order Chaetophorales

Coleochaete nitellarum	Jost	Abundant on Chara sp.
Microthamnion kuetzingianum	Naegeli	Occasional on Nuphar.
Stigeoclonum subsecundum	Kuetzing	Occasional on Nuphar.

Order Oedongoniales

Oedogonium sp.		Common on most macrophytes.

Order Chlorococcales

Ankistrodesmus falcatus	(Corda) Ralfs	Rare on Nuphar.
Scenedesmus bijuga	(Turp.) Lagerheim	Rare on Equisetum fluviatile and Nuphar.
Scenedesmus dimorphus	(Turp.) Kuetzing	Rare on Equisetum and Potamogeton richardsonii.

Order Zygnematales

Mougeotia sp.		Common on all aquatic macrophytes.

Order Desmidiales

Cosmarium reniforme	(Ralfs) Archer	Occasional to common on Potamogeton richardsonii and Equisetum fluviatile.
Cosmarium subcrenatum	Hantzsch	Rare on Equisetum.
Cosmarium supraspeciosum	Wolle	Occasional on Equisetum.

Class Charophyceae

Chara sp. About 33% of the bottom was covered by dense meadows of Chara. Maturation was reached by mid-August.

Division Chrysophyta

Class Bacillariophyceae (Diatomeae)

Cocconeis spp. Epipelic on mud at station 2.

Cymbella prostrata (Berk) Cleve Common on Potomogeton richardsonii and P. praelongus.

Cymbella sp. Abundant on Nuphar variegatum, occasional on most other aquatic macrophytes.

Epithemia sp. Found in abundance with Cymbella on Potomogeton spp. and Nuphar; common on all other aquatic macrophytes. Epipelic associated with mat of blue-green algae.

Fragillaria spp. Epipelic, occasional occurrance.

Meridion circulare C.A. Agardh Rare on Nuphar.

Navicula spp. Abundant on Nuphar; common on Equisetum and Potamogeton spp. The most common epipelic diatom.

Nitzschia spp. Common as an epipelic on mud with mat of Oscillatoria.

Pinnularia tabellaria Ehrenberg Abundant on Nuphar. Common on all other aquatic macrophytes.

Pinnularia cardinalis	(Ehrenberg) Wm. Smith	Common on Nuphar and Potamogeton spp.
Pinnularia viridis	(Nitzsch) Ehrenberg	Common on Equisetum fluviatile.
Synedra spp.		Rare on Nuphar. Very common as an epipelic diatom in the mat of Oscillatoria spp.

Division Cyanophyta

Class Myxophyceae

Calothrix sp.		Rare, occasional on Equisetum.
Oscillatoria andustissima	West and West	Common on Equisetum.
Oscillatoria curviceps	C.A. Agardh	Occasional on Nuphar, Equisetum and Potomogeton spp. Co-dominant with Oscillatoria princeps as an epipelic forming a mat on the bottom mud.
Oscillatoria princeps	Vaucher	Abundant on most aquatic macrophytes. With O. curviceps, forming a mat on the bottom mud.
Oscillatoria tenuis	C.A. Agardh	Abundant on Nuphar and Potomogeton spp.
Rivularia haematitis	C.A. Agardh	Abundant in late summer on most aquatic macrophytes.
Scytonema sp.		Abundant on Potamogeton richardsonii.
Spirulina major	Kuetzing	Occasional on most aquatic macrophytes or as an epipelic.

Spirulina princeps	(West and West) G.S. West	Occasional on most aquatic macrophytes. Common as an epipelic.

Division Euglenophyta

Class Euglenophyceae

Euglena acus	Ehrenberg	Rare (one cell) on Nuphar.
Euglena elastica	Prescott	Rare on Nuphar.
Phacus swirenkoi	Skvortzow	Rare (one cell) on Nuphar.

The benthic community was codominated by *Oscillatoria princeps* and *O. curviceps*. These blue-green algae formed an extensive mat on the bottom sediments of most of the lake. Occasionally, the accumulation of gas bubbles within and under this mat during warm sunny weather resulted in the dislodging of parts of the mat which then floated at or near the surface. These and other benthic algae, together with algae of the Aufwuchs which were dislodged from their substrate by wind and current action, were found in the samples collected for quantitative analysis. Whenever there was doubt as to whether or not an alga was euplanktonic, it was excluded from quantitative analysis.

(iii) Zooplankton

The Ciliata and Rotifera represented the majority of the zooplankters found in Muir Lake. The numerous aquatic macrophytes that developed provided a wealth of habitats for these organisms. The ciliates were most abundant in late summer. The rotifers, *Dicranophorus*, *Keratella*, *Kellicottia*, *Rotaria*, *Trichocerca*, and *Mytilina* were found throughout the study. All but *Keratella* occurred in very small numbers. (rare to occasional). *Keratella* was the dominant zooplankter during the study and appeared in greatest numbers during May and June. The copepod, *Cyclops* and the cladoceran, *Daphnia* appeared in very sparse numbers from May to July. When a hole was bored through the ice in winter, *Chaoborus* larvae in small numbers appeared at the surface.

III Features of Hastings Lake Study Area

1. Physical Features

Figure 12, page 73 shows the bathymetric contour lines of Hastings Lake together with the sites of stations designated for quantitative sampling. Morphometric parameters are given on Table 14, page 74.

The portion of the lake in which station 2 is situated may be regarded as a separate lake since it has a separate basin. It is set off from the main body of the lake by a narrow channel of very shallow water not more than one meter in depth. This separate area of water is distinct in regard to physico-chemical conditions.

The main sources of water income for the lake are surficial drainage from a large watershed area and precipitation falling on the water surface. It has been suggested that ground water enters as springs since the water level showed remarkable stability during an extended period of dry years (Kerekes 1965). During periods of plentiful precipitation there is abundant inflow of water rich in dissolved substances from nearby Cooking Lake. Drainage of the lake is through Hastings Creek. This is a semi-permanent to permanent outlet which drains into Beaverhill Lake which drains into the North Saskatchewan River. The large surface to volume ratio makes evaporation another major form of water loss from Hastings Lake.

Seasonal water level changes are shown by Figure 13, page 76 and are similar to those observed at Muir Lake. A small increase took place after spring runoff but the bulk of the increase came after the heavy precipitation in June. After July 1, a steady decrease in the level resulting from evaporation was observed.

Figure 12. Bathymetric map of Hastings Lake showing sampling stations and water level stake site. Contour interval 1 meter.

HASTINGS LAKE

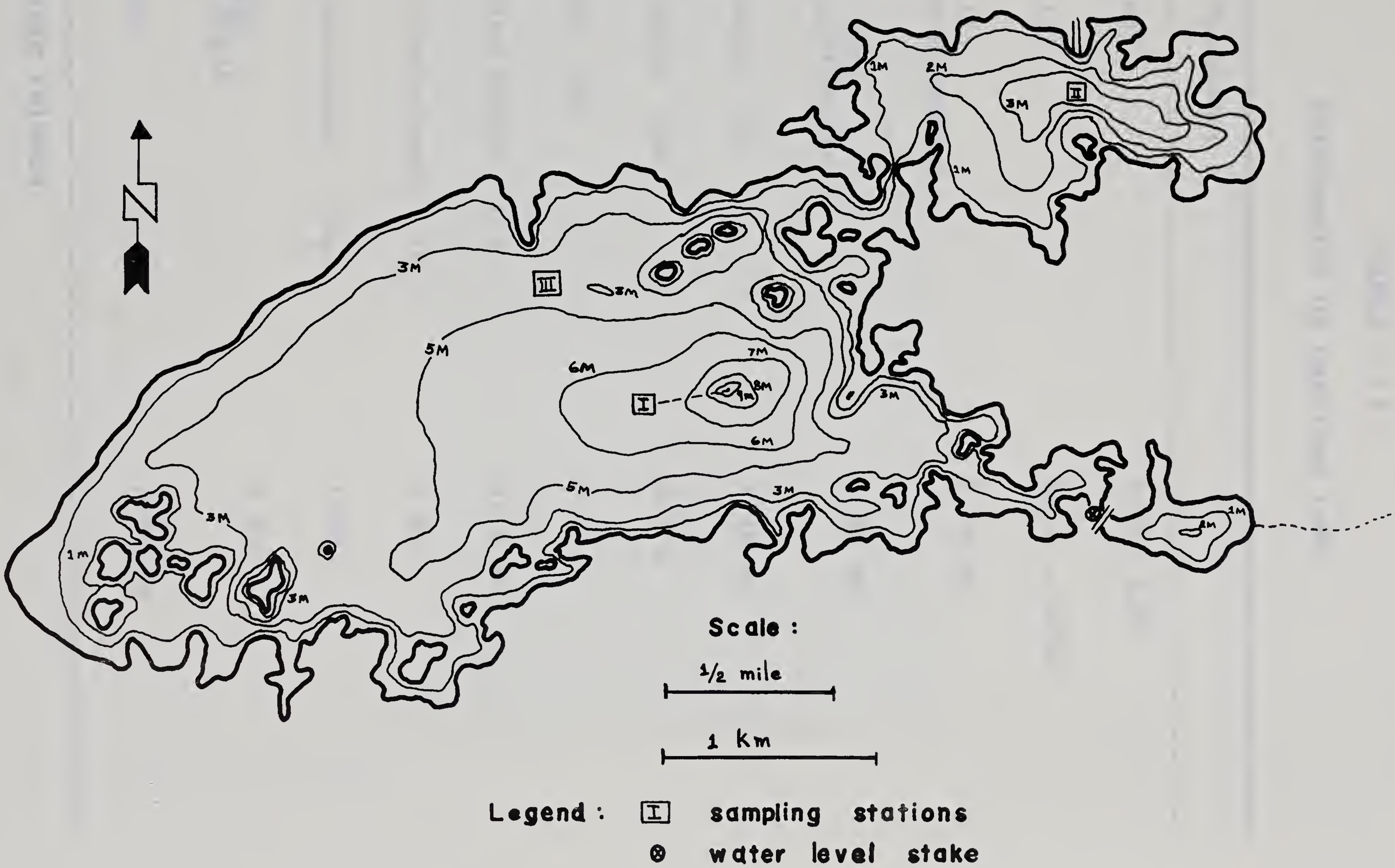


TABLE 14

Morphometry Of Hastings Lake

Parameter	
Area (Az)	8.710 km^2
Volume (V)	26.4 x $10^6 m^3$
Length (l) (Maximum Effective)	6.84 km
Breadth (bx) (Maximum Effective)	1.93 km
Mean Breadth ($\bar{b}$)	1.28 km
Maximum Depth (Zm)	8.7 m
Mean Depth ($\bar{Z}$)	3.03 m
* Shoreline Length (L)	37.6 km
Shoreline Development (D_L)	3.55
Volume Development (D_V)	1.04
$\frac{\text{Mean Depth}}{\text{Maximum Depth}}$	0.35
Elevation	736.3 m

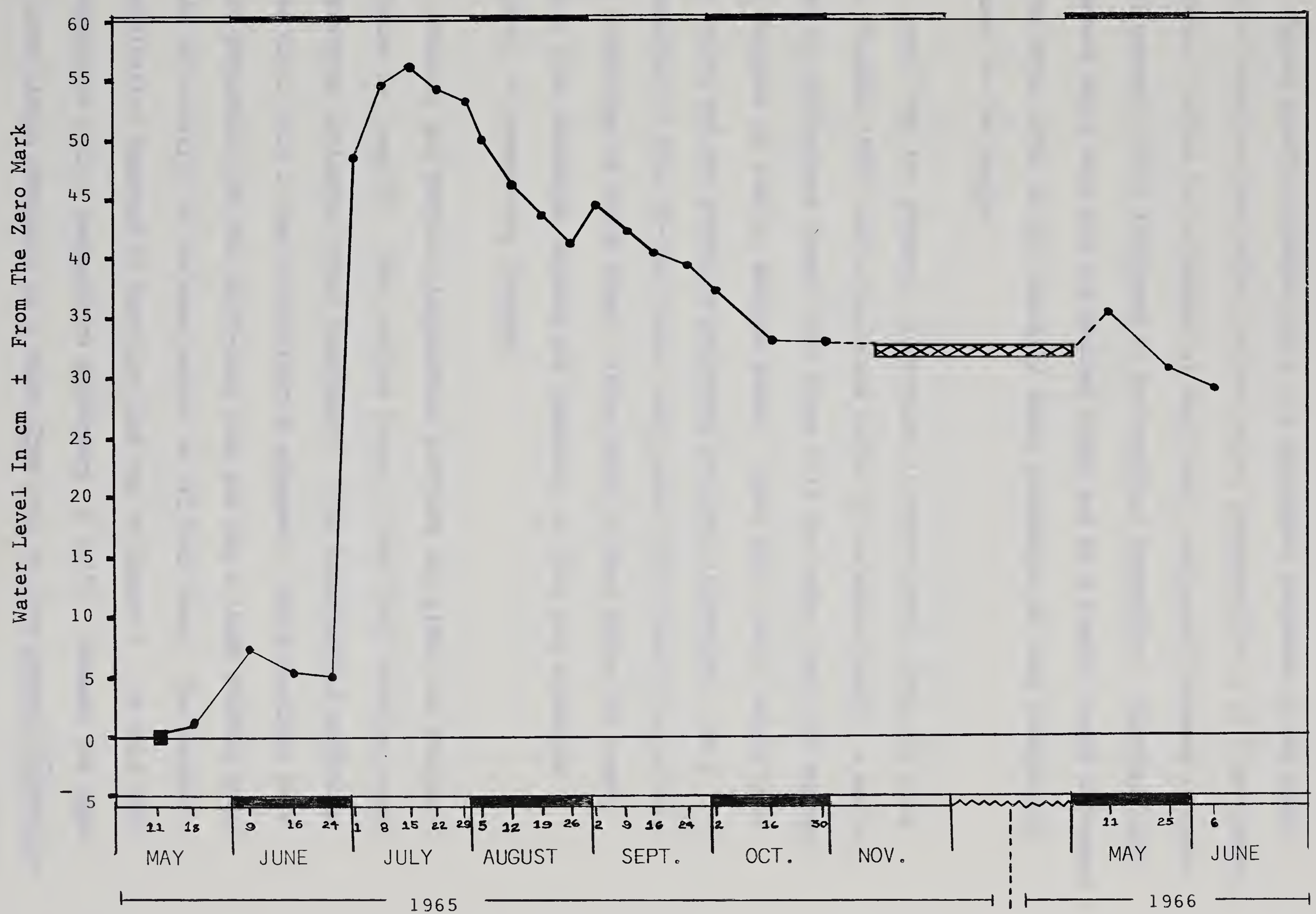
* Excluding Islands

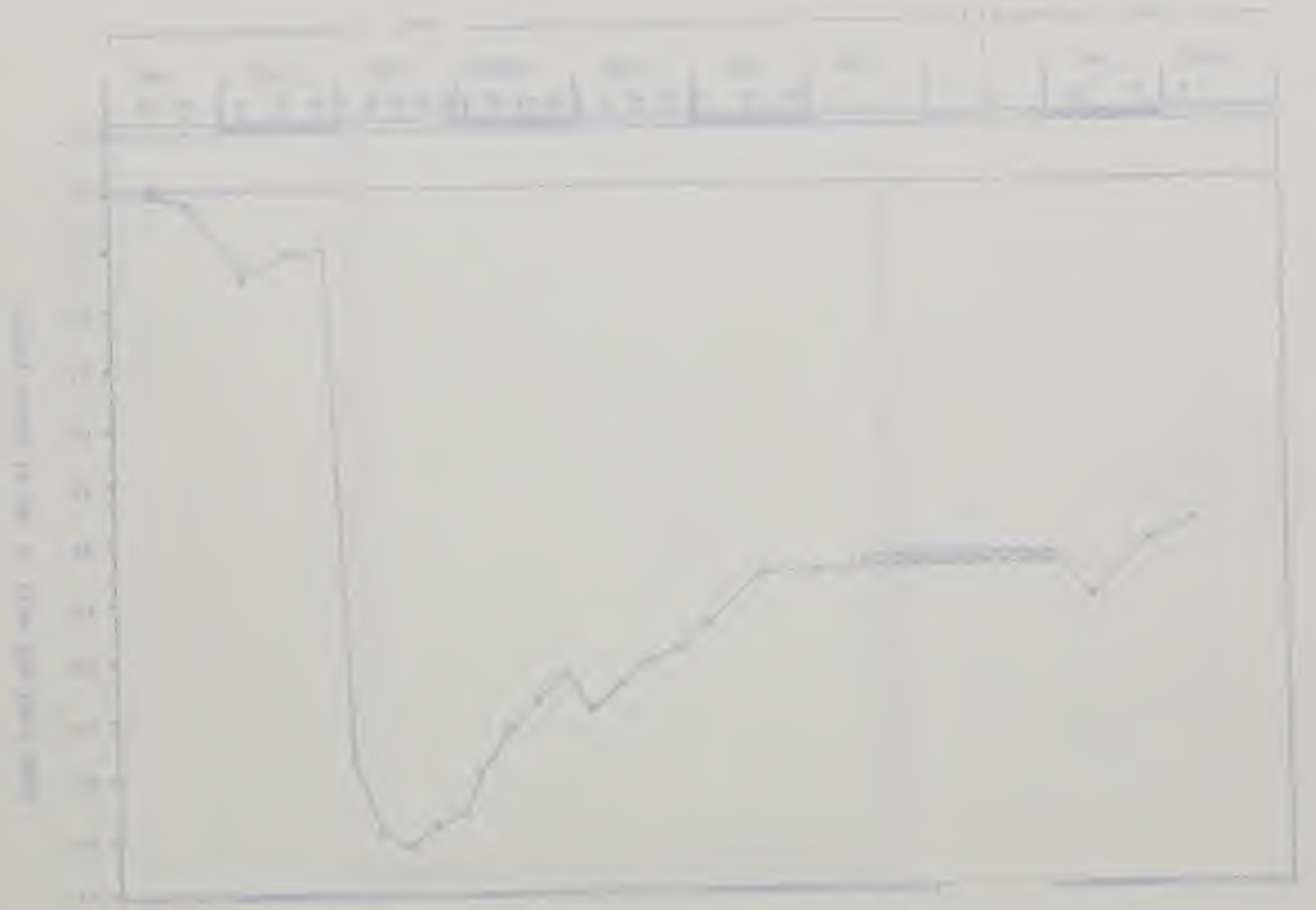
Plate 8. Hastings Lake as seen from an area north of station 1, looking towards the north shore. Photograph taken on May 25, 1966.

8.

Figure 13.

Changes in the Water Level of Hastings Lake For The Period May, 1965 to June, 1966





Spring runoff accounted for a 2.5 centimeter increase in the water level of Hastings Lake while the June rains accounted for a 43.5 centimeter increase. Unlike the situation at Muir Lake, this great increase in water level exerted little influence on the marginal vegetation. Hastings Lake possesses small wave and ice moulded banks and as a result, rapid increases in the water level do not normally cause inundation of land immediately adjacent to the margin.

Apart from the seasonal fluctuation in water level, data for this lake (Kerekes 1965) show a long-time cycle of the water level. A series of aerial photographs reveal that since 1916 the water level has receded many hundreds of feet in shallow areas. Since 1950, water levels have been rising and the shoreline perimeter has been increasing. As a consequence of this 50-year cycle, many paper birch *(Betula papyrifera)* tree stumps may be found today, rising about 10 feet above the water surface from submerged islands and hummocks, or from the submerged periphery of present-day islands.

Seasonal and vertical temperature profiles are given for station 1 in Figure 14, page 78. When studies began in June 1965, vertical water temperatures indicated vernal homothermy. This homothermous condition lasted until July 1 when stratification appeared. Since Hastings Lake is not protected from the north-west wind and has a large surface area, it did not stratify to the same extent as did Muir Lake. The maximum stratification observed at Hastings Lake was on August 5. On this date a thermocline with a temperature difference of 2.5°C. between the upper and lower limits developed at a depth from four to five meters (h profile line).

Figure 14. Seasonal water temperature profile for station 1 at Hastings Lake. For the key to the profile lines see Table 15, page 79.

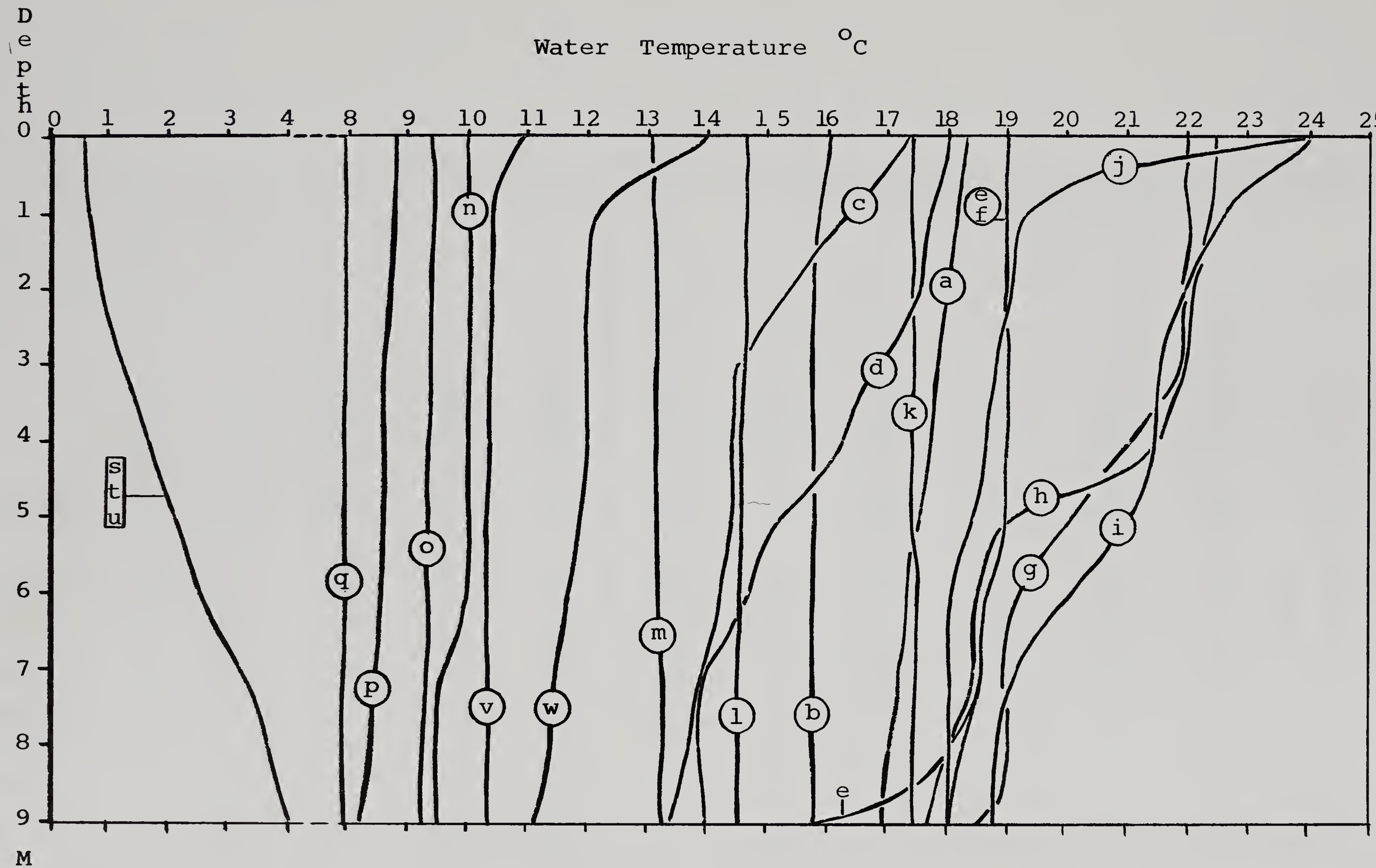

Water Temperature °C
Depth
M
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
s
t
u
v
w

TABLE 15

Seasonal And Vertical Water Temperature Series For Hastings Lake From June 16, 1965 to May 25, 1966

MONTH	KEY	DATE	0	1	2	3	4	5	6	7	8	9
JUNE	a	16	18.2	17.5	17.0	16.8	16.8	16.8	16.8	16.8	16.4	-
	b	24	16.0	15.8	15.7	15.7	15.7	15.7	15.7	15.7	15.7	-
JULY	c	1	17.5	16.3	15.3	14.5	14.5	14.5	14.2	14.0	13.9	-
	d	8	18.0	17.8	17.5	16.5	16.0	15.0	14.6	14.0	14.0	14.0
	e	15	19.2	19.0	19.0	19.0	19.0	18.8	18.5	18.0	16.0	14.5
	f	22	19.0	19.0	19.0	19.0	19.0	19.0	18.3	18.0	17.5	17.0
	g	29	22.0	22.0	21.5	21.5	21.0	20.0	19.2	19.0	19.0	18.7
AUGUST	h	5	22.4	22.4	22.0	21.5	[21.5	19.0	18.5]	18.5	18.2	18.0
	i	12	24.0	22.5	22.0	21.5	21.4	21.0	21.0	19.3	18.5	18.3
	j	19	23.8	19.2	19.0	18.6	18.3	18.3	18.1	18.0	18.0	18.0
	k	26	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4
SEPTEMBER	l	2	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.5	14.5
	m	9	13.1	13.1	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
	n	16	10.0	9.8	10.0	10.0	10.0	10.0	10.0	9.5	9.5	9.5
	o	24	9.3	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
OCTOBER	p	2	8.8	8.7	8.5	9.5	8.5	8.4	8.4	8.4	8.3	8.3
	q	16	7.9	7.8	7.8	7.8	7.8	7.8	7.9	7.9	7.9	7.9
	r	30	-	-	-	-	-	-	-	-	-	-
DECEMBER	s	18	0.6	0.6	0.9	1.2	1.6	2.0	2.3	3.1	3.5	4.0
FEBRUARY	t	5	0.6	0.6	1.2	1.8	2.2	2.5	2.7	3.2	3.5	-
MARCH	u	13	0.6	0.6	1.2	1.8	2.2	2.8	2.8	3.2	3.8	-
MAY	v	11	10.9	10.3	10.3	10.3	10.2	10.2	10.2	10.2	10.2	10.2
	w	25	14.0	12.1	12.0	-	12.0	-	11.6	-	11.4	-

-Thermocline in Brackets
-Water Temperatures in °C.

[illegible]

The high surface temperature of 23.8°C on August 19 (j) resulted from the absorption of heat by the "blooming" blue-green algae *Microcystis aeruginosa* and *Aphanizomenon flos-aquae*. These algae had accumulated at the surface as a result of the formation of pseudovacuoles in their cells. On August 26, homothermy was again established in the lake (k). During the period of autumnal homothermy, the difference in temperature of the surface water and that of the bottom water never exceeded 0.5°C.

Figure 15, page 82 gives ice cover measurements together with Secchi disc readings of water transparency. Freezeup took place during the week of November 7-13. In Hastings Lake complete freezing with the absence of open areas took place several days before this same condition was observed at Muir Lake. A similar discrepancy regarding the time of spring breakup was observed as Hastings Lake opened earlier than Muir Lake. The reason for this discrepancy may be attributed to the difference in total dissolved solids (T.D.S.) content of the two waters. The considerably higher T.D.S. of Hastings Lake probably results in a water with a much lower specific heat than that of Muir Lake water. Thus, the greater heat loss during autumn cooling leads to earlier freezeup. In the spring, the higher T.D.S. content of water and ice results in greater absorption of solar heat and as a result the ice melts more rapidly.

Seasonal Secchi disc water transparency data for the period of study are given in Figure 15, page 82. Hastings Lake showed the same pattern of seasonal changes in water transparency as did Muir Lake. The transparency of the water in Hastings Lake is less than that of Muir. In Hastings Lake the water is yellow-brown in color while the water of Muir

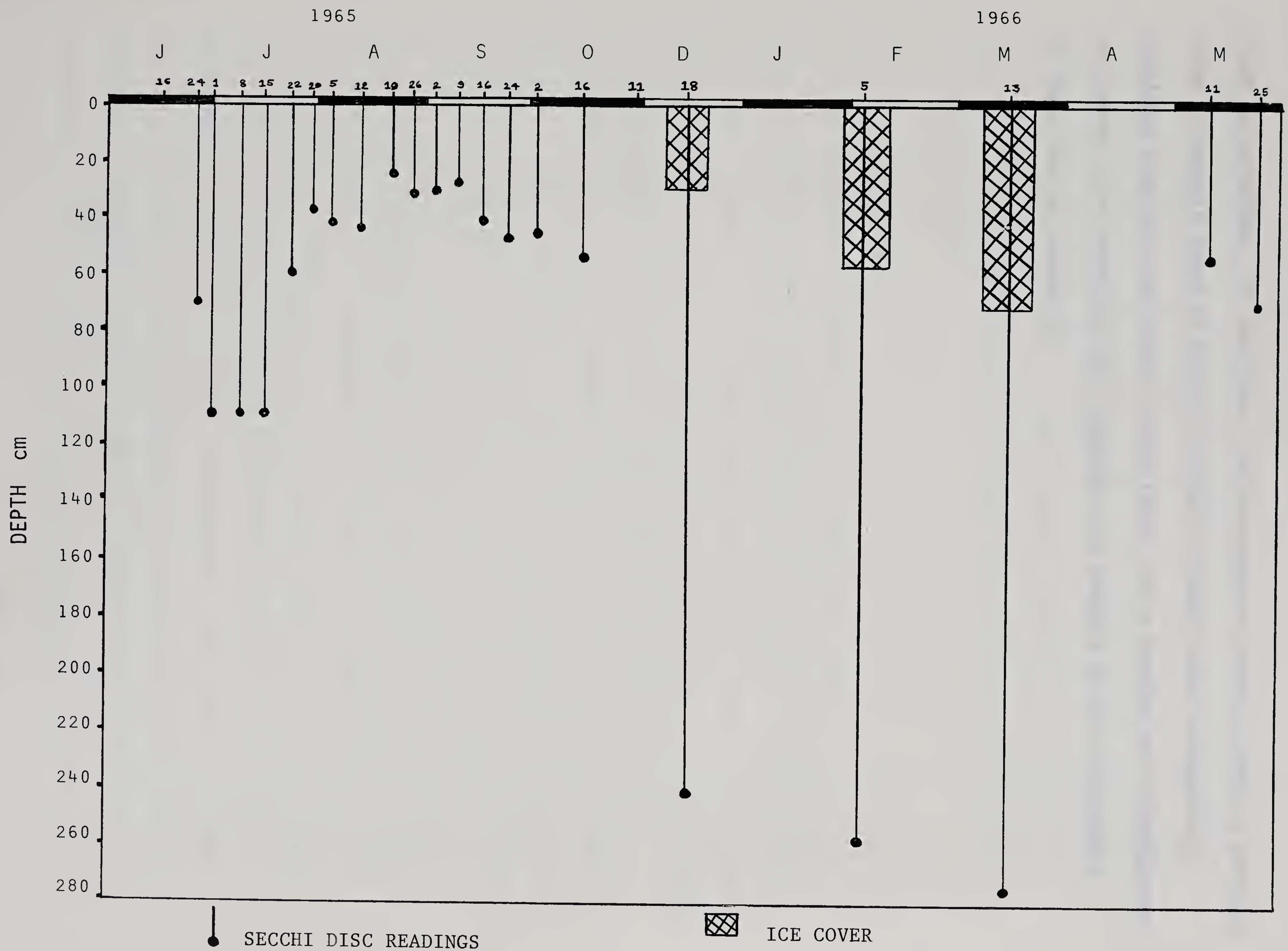
Plate 9. Hastings Lake as seen from the south shore (south of station 1) looking east-north-east showing the open shoreline and ice sheet about 30 meters from the shore. Photograph taken on May 2, 1966.

Plate 10. Hastings Lake as seen from the north shore looking across station 2. Photograph taken on May 2, 1966 showing the ice-free portion of the lake.

9.

10.

Figure 15. Seasonal secchi disc water transparency and ice cover measurements at station 1 in Hastings Lake for the period June, 1965 to June 1966.


1965
1966
J
J
A
S
O
D
J
F
M
A
M
DEPTH cm
SECCHI DISC READINGS
ICE COVER

Lake is colorless. In addition, the occurrence of water blooms in Hastings Lake at certain times of the year results in much lower transparency readings than are ever found in Muir Lake: eg, a reading of 25 centimeters on August 19 at Hastings Lake compared to a reading of 140 centimeters at Muir Lake on August 18.

2. Chemical Features

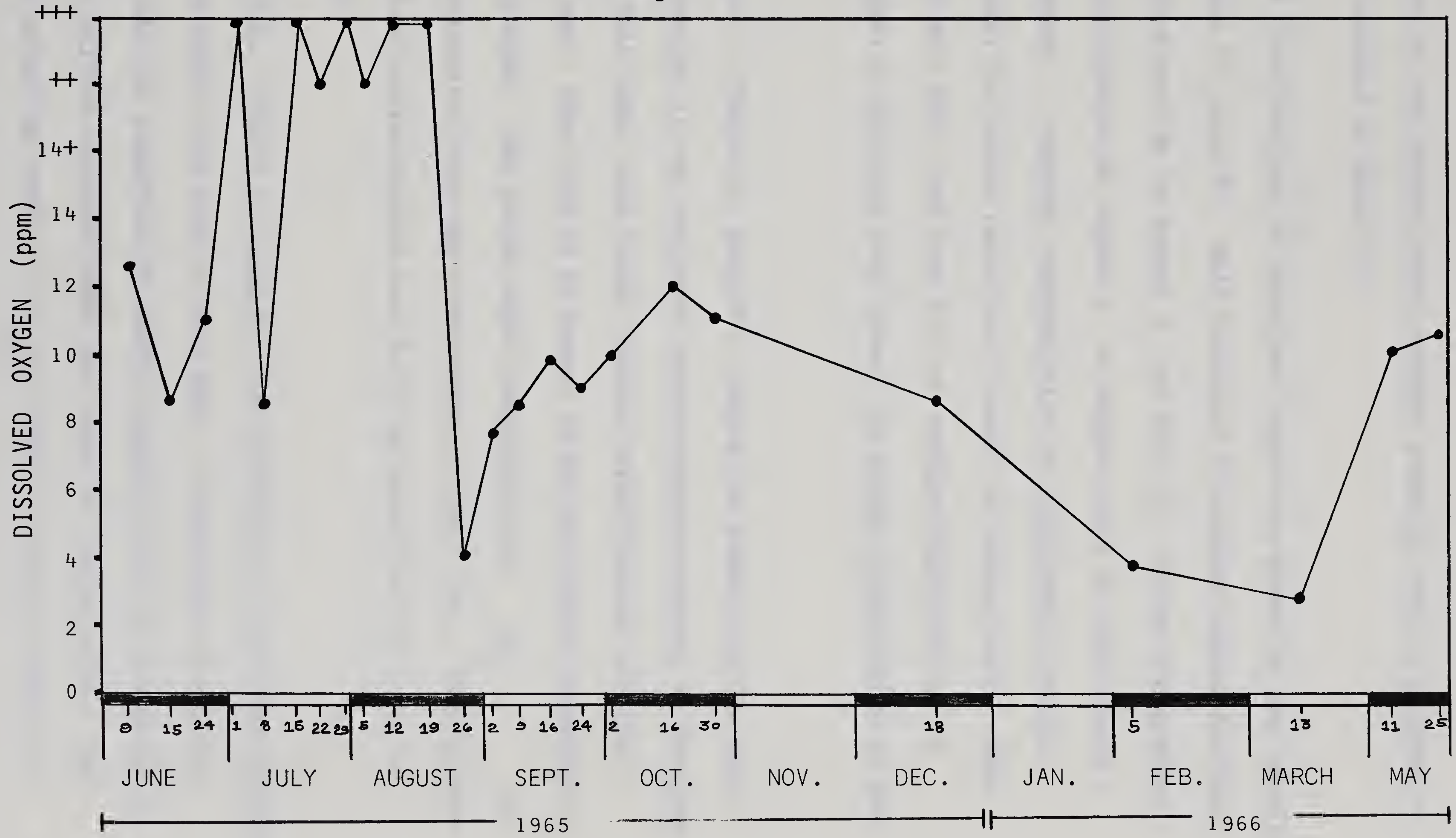
The chemical data discussed are those obtained in the field using the Hach Chemical Analysis Kit. Those data obtained from the laboratory of the Provincial Analyst are designated as P.A.D. Where no indication of station number is given the data are those obtained at station 1. The results of tests conducted at station 1 are given in Tables 16 and 17, pages 88 and 90.

(i) Dissolved Gases

Dissolved Oxygen: A seasonal cycle of dissolved oxygen is indicated by the data in Table 16, page 88 and Figure 16, page 85. Approximately a 6-fold increase in the maximum oxygen content of the water in mid-summer over the winter minimum was observed. The range through the period May to November inclusive was 4.05-14.+++ ppm. The method employed in the determinations could not measure the dissolved oxygen content of water beyond 14.0 ppm, therefore, + values are used to designate the qualitative concentrations beyond 14.0 ppm based on the intensity of color development of the test sample. More than 14.0 ppm of dissolved oxygen developed on at least 7 different sampling dates. The maximum concentration was found on August 19 and accompanied a bloom of blue-green algae. On the following week, the summer minimum dissolved oxygen was recorded (August 26). This decrease in dissolved oxygen was correlated with a sharp decrease in phytoplankton numbers, particularly the blue-green algae and to some extent the green algae which one week earlier were very abundant. Presumably, decomposition of the bloom algae caused this decrease in dissolved oxygen. As winter progressed, the dissolved

Figure 16.

Seasonal Distribution of Dissolved Oxygen From the Surface Water at Station 1 in Hastings Lake



oxygen content of the surface water dropped steadily until a minimum of 2.8 ppm was recorded on March 13.

Vertical distributions of dissolved oxygen are shown for six sampling dates in Figure 17, page 87. Well developed clinograde curves developed on several dates such as on August 5, and July 29. During the maximum seasonal stratification on August 5, no oxygen could be found below a depth of 4 meters. Frequent reoxygenation of hypolimnetic waters occurred through the summer period as a result of strong winds. When compared with Muir Lake, the data for the vertical distribution of dissolved oxygen in Hastings Lake reveal the higher productivity of the latter.

Carbon-Dioxide: (Table 16, page 88) During the summer period, much more stratification in the available carbon-dioxide occurred in Hastings Lake than in Muir Lake, even though thermal stratification was less in Hastings Lake. From July 29 to August 26 the epilimnion contained no free carbon-dioxide. The bottom water contained free CO_2 in greater concentrations than the bottom water of Muir Lake. High concentrations of free carbon-dioxide were built up under the ice cover at Hastings Lake.

Hydrogen Sulfide: (Table 17, page 90) The production of hydrogen sulfide took place throughout the year in this lake. Considerable anaerobic respiration with the reduction of sulfur compounds and the evolution of free hydrogen sulfide occurred under the cover of ice and snow. The surface water below the cover of ice was found to contain traces of

Figure 17. Vertical dissolved oxygen series for selected dates at station 1 in Hastings Lake.

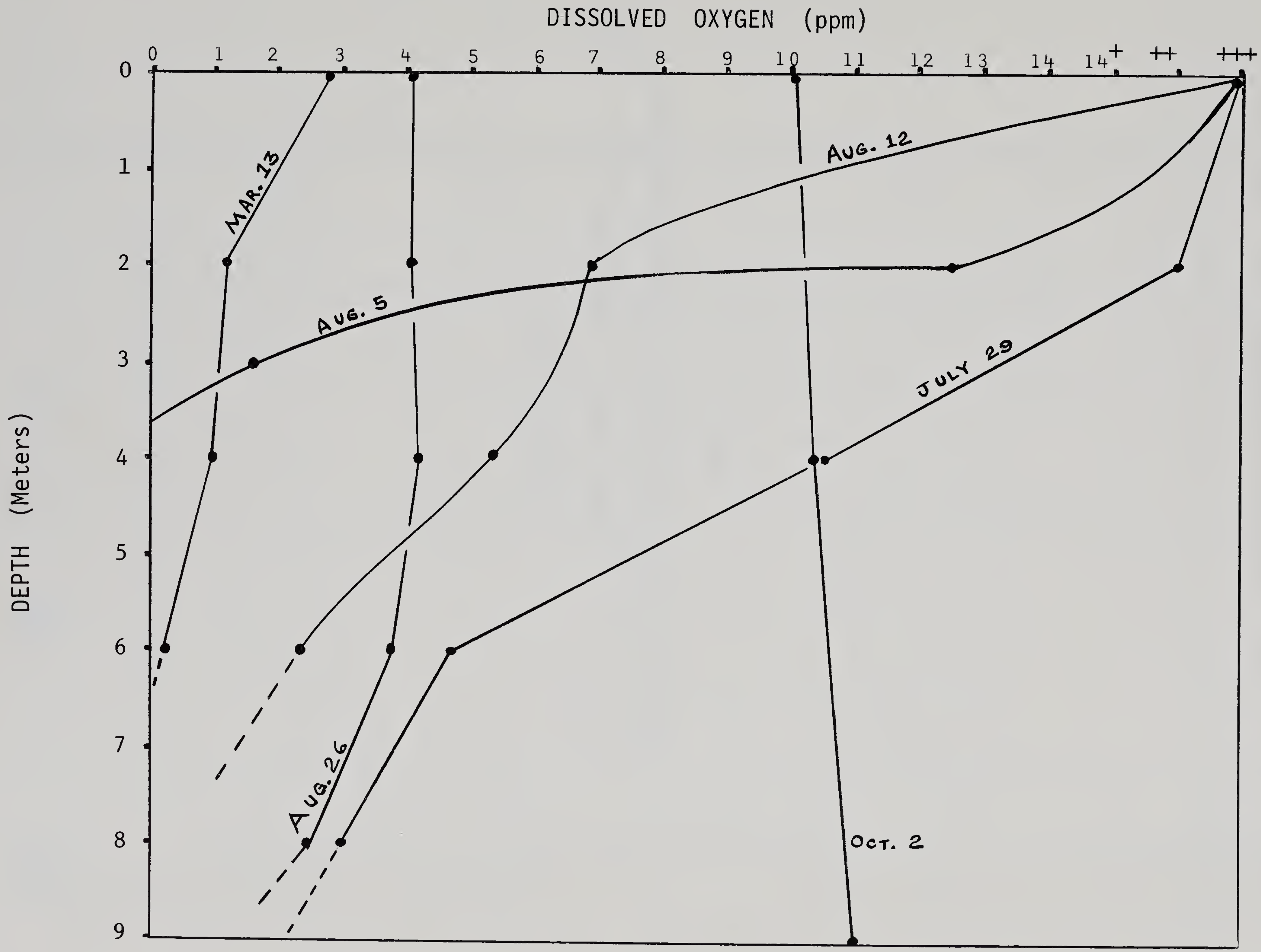

DISSOLVED OXYGEN (ppm)
DEPTH (Meters)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
14+
++
+++
MAR. 13
AUG. 5
AUG. 12
AUG. 26
JULY 29
OCT. 2

TABLE 16

Dissolved Gases And Hydrogen - Ion Concentrations At Station 1 On Hastings Lake For The Period June 9, 1965 To May 25, 1966

		JUNE			JULY					AUGUST				SEPT				OCT			DEC	FEB	MAR	MAY	
	DEPTH	9	16	24	1	8	15	22	29	5	12	19	26	2	9	16	24	2	16	30	18	5	13	11	25
OXYGEN ppm	0 M	12.5	8.5	11	14^{+++}	8.4	14^{+++}	14^{++}	14^{+++}	14^{++}	14^{+++}	14^{+++}	4.05	7.7	8.6	9.5	9.0	10	12	11	8.5	3.8	2.8	10	10.4
	2 M	-	6.0	10	14^{++}	6.4	-	14	14^{++}	12.5	6.8	11	4.05	7.7	8.6	9.2	-	-	-	-	-	3.0	1.2	-	-
	3 M	10.2	-	-	14^{++}	-	-	-	-	1.6	-	5.8	-	-	-	-	-	-	-	-	-	3.0	-	-	-
	4 M	-	6.2	10.2	14^{+}	4.4	14^{++}	11	10.5	Nil	5.4	8.2	4.2	8.2	9.5	9.6	9.0	10.4	-	-	6.8	3.0	1.0	10	9.0
	5 M	7.5	-	-	-	-	-	-	-	Nil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6 M	-	-	-	-	2.6	-	6.6	4.7	Nil	2.3	6.4	3.8	8.0	8.6	9.8	-	-	-	-	-	1.3	.2	-	9.0
	7 M	-	4.2	11	-	-	-	-	-	Nil	-	-	-	-	-	-	-	-	-	-	2.2	-	-	-	-
	8 M	-	-	-	4.7	2.5	-	4.5	3.0	Nil	-	4.9	2.5	7.5	8.7	9.8	9.0	11.0	-	-	-	.65	Nil	-	-
CARBON DIOXIDE ppm	0 M	6	10	16	4	12	0	0	Nil	Nil	Nil	2	8	28	50	14	20	12	-	-	80	72	40	16	16
	2 M	-	-	-	-	17	-	4	5	Nil	Nil	12	30	48	50	18	-	-	-	-	-	72	-	-	-
	3 M	12	14	28	-	-	-	-	-	8	-	60	34	40	-	-	-	-	-	-	-	-	-	-	-
	4 M	-	-	32	16	18	12	12	8	20	8	24	34	40	52	16	28	24	-	-	80	76	40	-	-
	5 M	14	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6 M	-	-	-	-	24	-	24	16	44	56	32	40	46	54	16	-	-	-	-	-	100	-	-	-
	7 M	-	20	104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80	-	-	-	-
	8 M	-	-	-	40	56	-	36	40	56	-	40	72	80	56	16	34	20	-	-	-	120	-	-	-
pH	0 M	8.4	8.6	8.7	8.8	8.4	9.0	9.4	9.4	9.5	9.6	9.8	9.0	9.0	9.0	8.8	9.0	9.0	9.0	-	8.6	8.4	8.7	8.6	8.7
	8 M	-	-	-	8.4	8.4	-	8.4	8.7	8.7	8.5	8.7	8.7	-	-	8.9	-	8.8	8.8	-	8.6	-	-	-	-
TIME OF SAMPLING hrs		1300	1300	1330	1315	1545	1200	1200	1300	1300	1200	1200	1130	1130	1230	1245	1400	1330	1345	1400	1445	1440	1500	1400	1300

hydrogen sulfide. At the same time the water at a depth of seven meters contained more than 5.0 ppm of free hydrogen sulfide. Although the surface water was free of hydrogen sulfide in summer, anaerobiosis in the bottom muds resulted in as much as 1 ppm of hydrogen sulfide in the water immediately above the mud-water interface.

(ii) Minerals in Solution

Silica: (Table 17, page 90) The silica concentrations varied seasonally and vertically. The vertical distribution resembled the distribution of most substances that are derived from the bottom sediments. These exhibit a high concentration at the bottom with a lower concentration at the surface of a water column.

The seasonal distribution of surface silica ranged in concentration from 0.18 - 9.6 ppm with a mean of 1.81 ppm. Several increases of short duration (one week or less) took place throughout the study. These increases in concentration were caused by winds, such as were observed on October 30. On that date a strong windstorm caused the mixing of bottom and surface waters resulting in a concentration of silica of 9.6 ppm at the surface.

Iron: (Table 17, page 90) The seasonal range of soluble iron concentrations for the period of study was 0.00 - 0.75 ppm at the surface and 0.001 - 0.06 ppm at the bottom. The mean surface iron concentration from twenty-two samples was 0.10 ppm.

After one month of thermal stratification and the stabilization of a clinograde oxygen curve, the iron content of the hypolimnetic water

TABLE 17

Chemical Data From Station 1 At Hastings Lake For

The Period June 9, 1965 To May 25, 1966

All Readings In ppm		JUNE 9	JUNE 16	JUNE 24	JULY 1	JULY 8	JULY 15	JULY 22	JULY 29	AUGUST 5	AUGUST 12	AUGUST 19	AUGUST 26	2	SEPT 9	SEPT 16	SEPT 24	2	OCT 16	OCT 30	DEC 18	FEB 5	MAR 13	MAY 11	MAY 25
ALKALINITY	Phenol.	-	10	10	30	30	30	40	60	40	50	70	40	40	30	30	30	30	20	20	10	10	10	10	15
	Carbon.	-	20	20	60	60	60	80	120	80	100	140	80	80	60	60	60	60	40	40	20	20	20	20	30
	Bicarb.	-	255	190	200	180	195	170	120	150	140	90	150	165	160	170	180	175	200	210	270	270	270	205	200
	Total	245	275	210	260	240	255	250	240	290	240	230	230	245	220	230	240	235	240	250	290	290	290	225	230
	P.A.D.	-	230	215	240	220	245	215	-	210	-	200	-	220	200	200	215	-	225	245	240	270	300	-	-
CHLORIDES	HACH	10	-	-	-	-	10	10	12.5	10	12.5	10	10	10	10	10	10	10	15	10	15	10	15	15	15
	P.A.D.	-	3	-	5	Nil	-	5	-	8	-	5	-	Nil	10	-	3	-	14	8	2	2	2	-	-
HARDNESS	Calcium	110	120	110	120	140	120	120	90	80	50	90	110	90	90	120	120	7	110	100	110	150	130	90	100
	Total	265	350	400	480	300	345	290	260	350	230	250	250	260	240	260	260	260	270	265	300	350	280	280	270
	P.A.D.	-	330	300	300	280	325	265	325	235	250	250	260	295	250	230	280	-	275	280	300	315	315	-	-
HYDROGEN SULPHIDE		Nil	Nil	Nil	S=0 B=5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B=5	S=0 B=5	S=trace M=2.5 B=5	-	-
SULPHATE	HACH	225	240	225	210	175	200	180	300	180	160	260	200	250	300	240	240	240	235	230	260	260	240	250	175
	P.A.D.	-	228	-	243	68	-	195	-	277	-	181	-	172	167	-	189	-	151	122	97	177	235	-	-
T.D.S.	P.A.D.	-	742	696	794	520	764	648	676	666	660	650	682	600	640	668	670	-	626	586	742	740	782	638	-
IGNITION LOSS	P.A.D.	-	204	218	220	276	200	174	222	143	228	210	210	250	216	244	210	-	210	220	204	280	226	-	-
ORGANIC MATTER	P.A.D.	-	93	122	48	153	58	148	79	40	118	112	-	154	128	156	124	-	110	95	97	128	-	-	-
CALCIUM	P.A.D.	-	45.6	-	48.1	-	-	44	35.2	37.2	35.2	39	40	58	57.6	54	54.4	-	46.4	56	44	45.6	52	-	-
MAGNESIUM	P.A.D.	-	-	-	-	-	-	-	-	34.5	-	37	38.9	36.4	25.7	-	35	-	38.6	34	46.2	48.8	44	-	-
SODIUM	P.A.D.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20.6	75.4	109.2	-	-
POTASSIUM	P.A.D.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20.5	30.0	33	-	-
CHLORINE		Trace	-	-	-	-	-	-	-	-	.001	Nil	.008	-	-	-	-	-	-	-	-	-	.	-	-
CHROMATE		.11	-	-	-	-	-	-	-	-	.125	-	.22	-	.14	.25	.25	.16	.19	.24	.41	.28	.26	.24	1.6
COPPER		.24	-	-	-	-	.14	.36	-	-	.12	.14	.08	.12	.09	.16	.06	.09	.05	.28	.18	.25	.14	.18	.16
IRON		.14	Nil	Nil	.08	1	-	.01	.08	.01	.01	Nil	.05	.10	.48	.42	.12	.01	.08	.19	.08	.75	.13	.18	.08
MANGANESE		Nil	.07	.15	-	-	.15	.65	.3	Nil	.25	Trace	.85	Nil	Nil	.75	.75	.30	.20	1.75	.40	1.2	.70	.70	.12
NITRATE N		.70	1.9	Nil	Nil	Nil	1.1	Nil	-	-	-	Nil	Nil	Nil	Nil	-	Nil	-	1.4	Nil	Nil	-	Nil	-	-
NITRITE N		.001	Nil	Nil	Nil	Nil	.003	Nil	-	-	-	Nil	Nil	Nil	Nil	-	Nil	-	Trace	Nil	Nil	.008	Nil	.005	Trace
PHOSPHATE	HACH ORTHO	.18	.09	.1	-	-	.26	.25	.10	3	.1	.36	.5	3	.15	.17	.22	.21	.01	.25	.14	.38	.40	.30	.205
	P.A.D. ORTHO	-	-	-	-	-	-	-	-	-	-	-	-	.68	.6	1.9	.9	-	.7	1.9	-	1.8	-	-	-
	P.A.D. TOTAL	.34	-	-	.3	1.0	-	.5	.5	.67	.8	.8	.58	1.28	.7	-	1.05	-	-	-	1.18	-	1.8	.58	-
SILICA		2.8	3	3	.37	S=1.2 B=2.4	.31	.47	1.9	1.05	2.4	2.35	1.34	.4	.2	.18	1.84	2.9	2.5	9.8	.44	1.5	1.16	.7	.15

Explanation of Abbreviations: P.A.D.- Provincial Analyst's Data
S- Surface
B- Bottom

Phenol.- Phenolphthalein
Carbon.- Carbonate
Bicarb.- Bicarbonate

increased from 0.005 to 0.06 ppm. A slight decline of ferrous iron from the surface waters occurred with the initiation of the autumnal overturn in September. The highest surface water iron content was recorded at 0.75 ppm during the winter stagnation period.

Sulfates: (Table 17, page 90) Hastings Lake is a high-sulfate lake. The range of sulfate concentrations were generally found to be 210 to 300 ppm with a mean of 228 ppm. The seasonal distribution of this ion was uniform with one exception. This exceptional concentration was recorded on May 26, 1966 as 175 ppm. No explanation could be formulated for the occurrance of this low concentration.

Chlorides: (Table 17, page 90) Chloride ions appeared in slightly higher concentrations in Hastings Lake than in Muir Lake. The range of concentrations of chlorides in Hastings Lake was 10-15 ppm with a mean of 11.5 ppm. An exceptionally uniform distribution of this ion occurred throughout the study period.

Nitrate-Nitrogen: (Table 17, page 90) The seasonal cycle of surface water nitrate-nitrogen in Hastings Lake followed the pattern of the cycle of nitrate-nitrogen described for Muir Lake. The mean concentration of nitrate-nitrogen in Hastings Lake was 0.317 ppm and the observed range was 0.0 - 1.9 ppm. Due to the paucity of determinations during the summer months, it is not known whether detectable concentrations appeared after July 15. Of those measurements taken during the summer, no detectable amounts of nitrates were found. Measurable concentrations of nitrate-nitrogen appeared in the spring and fall.

Nitrite-Nitrogen: (Table 17, page 90) The range of nitrite nitrogen was 0.0 - 0.008 ppm with a mean of 0.0006 ppm for twenty samples. The seasonal variations in surface concentrations of nitrites closely approximated the cycle of nitrate-nitrogen with the addition of traces of nitrites under the cover of ice.

Phosphorus: (Table 17, page 90) Much higher phosphorus concentrations were recorded for Hastings Lake than for Muir Lake. The range of detected ortho-phosphate phosphorus in the surface water of Hastings Lake was 0.01-3.00 ppm and the mean was 0.38 ppm. Highest ortho-phosphate phosphorus readings were obtained during autumnal overturn and during the period of winter stagnation.

Trace Elements: (Table 17, page 90) The mean chromate concentration for the period of study was 0.322 ppm (slightly higher than that found in Muir Lake), and the mean copper concentration was 0.158 ppm (slightly lower than the copper concentration of Muir Lake). The mean concentration of manganese was 0.39 ppm. More or less uniform seasonal distributions of these three trace elements were observed.

Cations: (Table 17, page 90) Mean concentrations and ranges of calcium, magnesium, sodium and potassium were: 47, (35.2-58.0); 38, (25.7-48.8); 69, (20.6-109.2) and 28, (20.5-33.0) ppm respectively. Sodium and potassium ions tended to become concentrated during the winter. Calcium ions increased progressively through the summer and winter and then dropped markedly during spring breakup.

(iii) Other Substances in Solution

Total Dissolved Substances (T.D.S.) (Table 17, page 90) The range of T.D.S. concentrations for station 1 was 482-782 ppm with a mean of 648 ppm. Station 2 showed a range of 430-742 ppm T.D.S. with a mean of 579 ppm.

Summer evaporation increased the concentration of T.D.S. slightly with a sharp increase during the period of ice formation. Since water contains little T.D.S. when it freezes, a concentration in the amount of T.D.S. in the water column by "freezing out" took place in winter.

Organic Matter: (Table 17, page 90) Station 1 showed an organic matter mean concentration of 104 ppm for a range of 40.0-156 ppm. Station 2 had a slightly higher organic matter content than Station 1. Station 2 had a mean concentration of 108 ppm for a range of 6-178 ppm. Both of these stations at Hastings Lake showed an increase of nearly twofold in their organic matter content over Muir Lake water. Minimal readings were obtained on July 15 at both stations at which time the numbers of the diatom *Stephanodiscus astraea* were greatest.

Hardness: (Table 17, page 90) The water of Hastings Lake is "very hard", based on the U.S. Geological Survey classification of waters based on hardness in calcium carbonate content. The mean total hardness of station 1 for the study period was 294 ppm, which was much higher than the lower limit of the Geological Survey's "very hard" classification of 180 ppm.

The seasonal fluctuation in hardness at station 1 ranged from 230-480 ppm

in terms of the amount of $CaCO_3$. High hardness readings occurred during December and February, but during March the hardness dropped 70 ppm as a result of a sharp decrease in the free CO_2 concentration during a period of increased algal growth. Throughout the study sudden increases in total hardness were accompanied by rapid decreases in the amount of free carbon-dioxide.

Alkalinity: (Table 17, page 90) The mean alkalinity for station 1 for the study period was 245 ppm. The mean carbonate alkalinity was 54 ppm and the mean bicarbonate alkalinity was 191 ppm. The seasonal fluctuation in total alkalinity showed a similar pattern as discussed for Muir Lake with a winter high decreasing upon spring thaw dilution. In Hastings Lake, considerable local variation in bicarbonate and carbonate alkalinities occurred on two separate occasions. On July 29, the bicarbonate alkalinity dropped to 120 ppm from the July 22 reading of 170 ppm. At the same time, the carbonate alkalinity rose to 120 ppm from the July 22 level of 80 ppm. On July 29, there occurred a complete absence of free carbon-dioxide in the surface water and the abundant growth of *Anabaena flos-aquae*. It is suggested that the depletion of free carbon-dioxide from the surface water resulted from the photosynthetic activities of *Anabaena flos-aquae* (plus other blue-green algae) and the consequent dissociation of bicarbonates to yield carbon-dioxide for the algae. On August 19 a decrease in bicarbonate alkalinity was accompanied by an intense phytoplankton bloom of *Aphanizomenon flos-aquae* and *Microcystis aeruginosa*. Once again, depletion of free carbon-dioxide resulted in the decomposition of the bicarbonates to yield CO_2 for continued algae growth.

The alkalinity of Hastings Lake water is much higher than the alkalinity of Muir Lake water. The sudden decrease in bicarbonate alkalinity and increase in carbonate alkalinity as a result of intense phytoplankton development was a much more striking phenomenon in Hastings Lake than in Muir Lake.

Hydrogen-Ion Concentration: (Table 16, page 88) Hastings Lake had a surface water pH range of 8.39-9.75 with a mean of 8.95 for the study period. The mean pH for the bottom water was 0.30 pH units lower than that found at the surface. The low surface pH of 8.39 was recorded on July 8 and was correlated with a rise in the content of free carbon-dioxide. This rise in surface-free CO_2 resulted from reduced photosynthetic activity (very cloudy day) and the mixing of CO_2-rich bottom waters by strong winds. The high pH of 9.75 was recorded on August 19. This date marked the height of photosynthetic activity.

December and February showed reductions in pH values from 8.92 on October 16 to 8.65 and 8.64 respectively. A slight increase to 8.70 took place by March 13 during a period of increased phytoplankton activity and the accompanying decrease in free carbon-dioxide.

(iv) Chemistry of the Bottom Sediments and Ice

Bottom Sediments: Table 18, page 97 shows the results of the chemical analyses of bottom sediments from station 1 and station 2. The nature of the bottom sediment chemistry reflects the very high sulfate concentration and relatively high conductivity of the lake water.

Ice: (Table 19, page 97) The ice samples obtained on February 5 were taken from a depth that was ice-free on December 20. As a result of the sampling, the T.D.S. and ignition loss were lower on the later date. As found for Muir Lake, the orth-phosphate phosphorus at Hastings Lake was concentrated in the ice.

TABLE 18

Chemical Analysis Of The Bottom Sediments In Hastings Lake From Samples Collected During The Winter (December 18 and February 5)

Sample	lbs/acre nutrients N	P	K	pH	Cond. (mmho)	Sulfates	Free Lime
Stn. 1	Nil	12	600^{+}	7.4	5.5	Very High	Low^{+}
Stn. 2	Nil	18	600^{+}	7.4	4.0	Very High	Med.

TABLE 19

Chemical Analysis Of Hastings Lake Ice Water (P.A.D.)

Station	Date	T.D.S.	Ignition Loss (ppm)	Ortho-Phosphate Phosphorus (ppm)
1	Dec. 18	68	36	0.75
2	Dec. 18	-	-	-
1	Feb. 5	35	18	1.20
2	Feb. 5	20	9	1.50

3. Biotic Features

(i) Aquatic Macrophytes

Floating Macrophytes: One plant was included in this category because of its floating leaves. *Ploygonum amphibium* var. *stipulaceum* appeared occasionally along the margin of the lake and margins of the many islands. Flowering of this aquatic took place in early September.

Emergent Macrophytes: The emergent macrophytes found in Hastings Lake are shown in Table 20 with their relative abundance.

TABLE 20

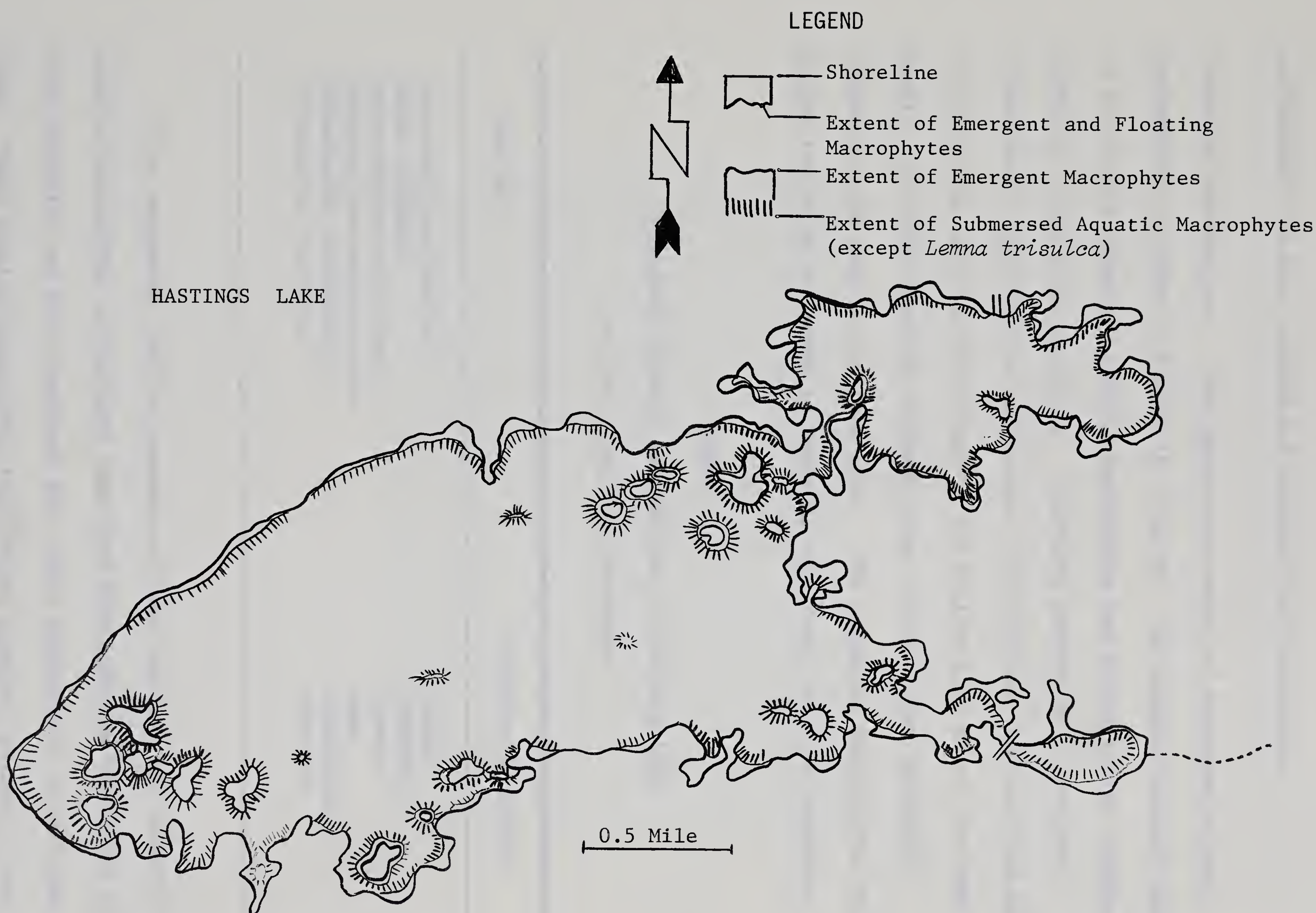
Emergent Aquatic Macrophytes In Hastings Lake

And Their Relative Abundance

Species	Relative Abundance
Eleocharis palustris	Occasional
Phragmites communis	Common
Scirpus acutus	Common
Scirpus validus	Occasional
Typha latifolia	Common

Figure 18, page 99 shows the approximate extent of the emergent macrophytic zone. *Typha latifolia* and *Scirpus validus* formed thick growths in the many shallow bays, particularly in the north-west portion of the lake. *Scirpus acutus* formed dense stands in shallow areas within the large portion of the lake. *Phragmites communis* in large stands,

Figure 18. Map of Hastings Lake showing the extent of the zones of Floating, Emergent and Submersed Aquatic Macrophytes.


LEGEND
Shoreline
Extent of Emergent and Floating Macrophytes
Extent of Emergent Macrophytes
Extent of Submersed Aquatic Macrophytes (except *Lemna trisulca*)
HASTINGS LAKE
0.5 Mile

surrounded the many islands and bordered the lake margin.

Submersed Macrophytes: The approximate extent of submersed aquatic macrophytes is shown in Figure 18, page 99. The maximum lakeward extent of the rooted submerged aquatic macrophytes was marked by the abundant growth of *Potamogeton vaginatus*. Clustered growths of *Potamogeton richardsonii*, *Myriophyllum exalbescens*, *Myriophyllum verticellatum* and *Ceratophyllum demersum* were found in the shallow bays along the west margin. The free floating duckweed, *Lemna trisulca*, grew abundantly throughout the year in the lake water. The submersed macrophytes found during the study are shown in Table 21 with their relative abundance.

TABLE 21

Submersed Aquatic Macrophytes In Hastings Lake

And Their Relative Abundance

Species	Relative Abundance
Ceratophyllum demersum	Common
Lemna trisulca	Abundant
Myriophyllum exalbescens	Common
Myriophyllum verticellatum	Rare
Potamogeton richardsonii	Occasional
Potamogeton vaginatus	Abundant

It is suggested that the presence of fewer species and numbers of aquatic macrophytes in Hastings Lake than Muir Lake was the result of high turbidity and the consequent poor light penetration in Hastings Lake. Those aquatic macrophytes that formed abundant growths in the

Plate 11. Emergent aquatic macrophytes: *Phragmites communis*, *Typha latifolia*, and *Scirpus validus* at the north shore of Hastings Lake on October 17, 1965.

shallow waters of Hastings Lake were plants that could tolerate light of low intensity and unfavourable quality as a result of turbid waters.

(ii) Benthic and Aufwuchs Algae

Of the algae from these two communities, only a few species from the Aufwuchs were represented in Hastings Lake. Low light penetration and the thorough scouring of the bottom sediments by wind-induced wave action were largely responsible for the absence of benthic algae. The presence of only five species of algae from both communities can be explained by the unfavourable habitat factors such as substrate and light conditions.

(iii) Zooplankton

Almost the entire crop of zooplankton was made up of *Gammarus lacustris*, *Hyalella azteca*; the copepods, *Cyclops*, and *Diaptomus*, and nauplius Larvae. The most persistent and dominant zooplankters were *Gammarus lacustris* and *Hyalella azteca*. These two crustaceans appeared in tremendous numbers throughout the ice-free period. *Daphnia* and *Cyclops* appeared in large numbers in spring. On March 13, large numbers of *Daphnia magna* (colored red due to the accumulation of pigmented lipids) appeared under the ice cover. *Chaoborus* larvae, in small numbers, were found at this time. The rotifers *Mytilina* and *Keratella* were found in very small numbers.

Hastings Lake: Benthic And Aufwuchs Algae With Notes On Their Relative Abundance And Substrate

Division Chlorophyta

Class Chlorophyceae

Order Chaetophorales

Coeleochaete soluta (de Bréb) Pringsheim — Abundant on Typha latifolia in late summer.

Division Chrysophyta

Class Bacillariophyceae

Epithemia sp. — Common on Phragmites and Scirpus.

Navicula sp. — Common on Potamogeton vaginatus.

Pinnularia viridis (Nitzsch) Ehrenberg — Rare on Potamogeton vaginatus.

Division Cyanophyta

Class Myxophyceae

Rivularia haematitis C.A. Agardh — Abundant on Potamogeton vaginatus, Ceratophyllum demersum and Myriophyllum spp.

RESULTS

A. Species Composition and Seasonal Succession

A presence list of the phytoplankton in each study lake was drawn up giving brief notes on their time of occurence and relative abundance. This list preceeds the description of the seasonal succession of plankton algae.

In the account of phytoplankton seasonal succession in the two lakes under study, only the more important phytoplankton species are considered. Those species that occurred rarely or occasionally with respect to the entire phytoplankton community are not discussed. However, the quantitative results of all the phytoplankton enumerated during the study are given in Appendix B, pages 212 to 216, inclusive.

For convenience in presenting the seasonal succession of the plankton algae, the important algae have been placed in one of three categories:
(i) Dominant (or codominant if more than one species is involved). This category is composed of the phytoplankton species that is more abundant (based on numerical units) than any other single species.

(ii) Sub-dominant. This category contains one or more species each of which, when considered alone, is numerically less abundant than the dominant or codominant species but is still present in considerable numbers.

(iii) Subordinate. This category refers to those algae of more than occasional (one or two cells per milliliter of sample) occurrence but which are conspicuously fewer in numbers than the sub-dominant species.

The following table will serve to illustrate my application of these three terms.

TABLE 22

Important Algae In Muir Lake On July 21, 1965

Category	Alga	No. of Cells/ml.
Codominant	Anabaena flos-aquae	456
	Anabaena circinalis	388
Sub-dominant	Asterionella formosa	28
	Coelastrum microporum	50
	Dinobryon spp.	38
	Mallomonas acaroides	65
Subordinate	Cosmarium punctulatum	4
	Staurastrum curvatum var. asterionelloides	4
	Scenedesmus spp.	13

It should be pointed out that numerous difficulties arise when an attempt is made to choose the alga that plays the greatest role in the total phytoplankton community, from a group of several species whose

"numbers" are equal. The difficulty arises because of the factor of cell size. One cell of a *Pediastrum boryanum* coenobium, possibly plays a smaller role in the economy of the total phytoplankton community than does one cell of *Stephanodiscus astraea*, since approximately four cells of this diatom would occupy more volume of water than one coenobium (36 cells) of *Pediastrum boryanum*. Misconceptions could arise if only cell numbers are used as the criterion on which to base dominance. If species units, that is, single cells for unicellular algae and coenobia for colonial forms, are used as the criterion for ranking species, certain difficulties and false impressions could arise. One cell of the green alga *Chlamydomonas globosa* may not play as large a role in the phytoplankton community as one colony of the blue-green alga *Coelosphaerium naegelianum* (average of 128 cells/colony). A unicellular alga may be found to change rapidly in numbers as changes in the environment occur, but because of its small size, this change may not show if only unit volumes are considered.

I have chosen to use cell numbers as the criterion for ranking the individual species and unit numbers as the criterion for ranking the groups (at the divisional or class level) of phytoplankton. I consider that this provides a sound basis for comparison of changes from one month to the next for both the individual species and the groups of plankton algae.

The description of the seasonal succession of important phytoplankton species is given on a monthly basis. During the May to October period, each month is divided into two parts. The seasonal changes are summarized for the first two weeks (I) and for the last two weeks (II) of the month.

1. Muir Lake

Species Composition

Presence List Of Phytoplankton With Notes On Their

Time Of Occurrence And Relative Abundance

Division Chlorophyta

Class Chlorophyceae

Order Volvocales

**Chlamydomonas globosa*	Snow	Dec. to May.	Abundant in Dec. and very abundant in March.
Chlamydomonas angulosa	Dill	Dec. to March.	Occasional.
Chlamydomonas polypyrenoideum	Prescott	Dec. to March.	Rare.
Eudorina elegans		Oct. to Nov.	Rare.
**Pandorina morum*	(Muell.) Borg	July to May.	Occasional.

Order Tetrasporales

Gleocystis major	Gerneck (Lemmermann)	Sept. to Nov.	Occasional.

Order Ulotrichales

Hormidium klebseii	G.M. Smith	Oct.	Rare.
Ulothrix subtilissima	Rabenhorst	Oct. to Nov.	Rare.

Order Sphaerpleales

Spaeroplea annumlina	(Roth) C.A. Agardh	May 12, 1966.	Rare.

Order Microsporales

Microspora stagnorum	(Kuetz.) Lagerheim	May 12, 1966.	Rare.

Order Chlorococcales

**Actinastrum hantzschii*	Lagerheim	June to July.	Rare.
**Ankistrodesmus falcatus*	(Corda) Ralfs	June to May.	Found throughout the study. Common in August.
Botryococcus sudeticus	Lemmermann	Nov. to Dec.; March.	Common in late fall and winter.
**Cerasterias staurasteroides*	West & West	June; Aug. to Sept.	Most common during the autumn.
Closteriopsis longisima	Lemmermann	Oct. to Nov.	Rare.
**Coelastrum microporum*	Naegeli	June to July.	Occasional.
**Crucigenia tetrapedia*	(Kirch.) West & West	Dec. to May.	Rare. Greatest numbers beneath ice.
Kirchneriella lunaris	(Kirch.) Moebius	Appeared in culture only.	
**Lagerheimia quadriseta*	(Lemm.) G.M. Smith	Sept. to June.	Common Greatest numbers in late fall and winter.
Micractinum pusillum var. *elegans*	G.M. Smith	May.	Rare.
**Oocystis parva*	West & West	Dec.; May.	Occasional
Oocystis borgei	Snow	May.	Rare.

Pediastrum araneosum var. *rugulosum* G.S. West June. Rare.

**Pediastrum boryanum* (Turp) Meneghini June;Oct. Occasional.

**Pediastrum duplex* Meyer June; Sept to Oct. Occasional.

**Pediastrum tetras* (Ehrenb.) Ralfs March to June. Occasional.

Pediastrum tetras var. *tetraëdron* (Corda) Rabenhorst March to June. Occasional.

**Pediastrum obtusum* Lucks March to June. Occasional.

Planktospaeria gelatinosa G.M. Smith Nov. Common.

Quadrigula lacustris (Chod.) G.M. Smith March to May. Rare. Abundant in culture.

**Scenedesmus bijuga* (Turp) Lagerheim June; Aug. to Sept. Occasional to common.

**Scenedesmus dimorphus* (Turp) Kuëtzing June to June. Common throughout study. Most abundant in Aug. - Sept.

Scenedesmus quadricauda var. *Westii* G.M. Smith May to June. Rare.

Tetraëdron arthrodesmiforme (G.S. West) Woloszýńska Sept. to Oct. Rare.

**Tetraëdron limneticum* Borge Aug. to Sept. Occasional.

Teteaëdron minimum (A. Braun) Hansgirg Nov. to Dec. Rare. Common in culture.

Teteaëdron trigonum var. gracile (Reinsch) De Toni Aug. to Nov.; Mar. to June. Occasional to common.

**Treubaria setigerum* (Archer) G.M. Smith May. Common.

Trochiscia zachariasii Lemmermann Dec. to May. Occasional to Common.

Order Zygnematales

Mougeotia sp. May to July. Common in shallow grassy bays. Most common in May. Never found to conjugate.

Spirogyra spp. May to July; Sept. to Oct. Common in shallow grassy bays. Only one filament found conjugating in October.

Zygnema sp. May to July. Occasional in shallow grassy areas. Never found to conjugate.

Order Desmidiales

**Cosmarium punctulatum* Brébisson June to June. Rare throughout the study period.

Cosmarium reniforme (Ralfs) Archer June to July. Rare.

Spondylosium planum (Wolle) W. & G.S. West July. Rare.

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Staurastrum curvatum var. *paradoxum* June to Oct. Occasional.

Staurastrum polymorphum Brébisson June to Oct. Rare to Occasional.

Division Chrysophyta

Class Chrysophyceae

**Dinobryon divergens* Imhof June to July; May to June. Common along with the dominant species Dinobryon sertularia and the rare species Dinobryon sociale. Reached a peak in spring of 1965 and 1966.

**Dinobryon sertularia* Ehrenberg June to July; Sept. to Oct; May to June. Became the dominant Chrysophyte during the times indicated. Distinct spring and autumn peaks.

Dinobryon sociale Ehrenberg June to July; May to June. Rare.

**Mallomonas acaroides* Perty June to June. Found throughout the study period. Reached a peak on July 28, 1965 with most of the cells concentrated at a depth of five meters where the oxygen concentration was minimal.

Mallomonas pseudocoronata Prescott Sept. Rare. Only several cells were observed.

**Synura uvella* Ehrenberg Oct. to Nov.;May. Common during fall pulse. May pulse was of short duration.

**Uroglenopsis americana* (Calkins) Lemmermann. Oct. This species was very abundant on Oct. 17. Peak of short duration since no colonies of this species were observed on either Oct. 1 or Nov. 1.

<u>Class</u> <u>Bacillariophyceae</u> <u>(Diatomeae)</u>

Achnanthes spp. July to Nov. Rare.

**Asterionella formosa* Hass. June to July; Sept. to Nov.; May. Common Two pulses: first during the period from May to July; second during the period Sept. to Nov.

Cocconeis spp. July to Nov. Occasional.

Epithemia spp. July to Nov. Occasional.

Fragillaria spp. July to Nov. Occasional.

Gomphoneis angustatum (Kuetz) Rahb. July to Nov. Rare.

Hantzschia sp. July to Nov. Occasional.

Meridium sp. July to Nov. Rare.

Navicula spp. July to Nov. Occasional.

Pinnularia sp. July to Nov. Rare.

Pleurosigma angulatum (Quekett) Wm. Smith July to Nov. Rare.

Rhopalodia sp. July to Nov. Rare.

**Synedra ulna* (Nitzsch) Ehrenberg Common to abundant from Nov. to June. First pulse in late autumn-early winter and a second pulse in early spring.

Tabellaria floculosa (Roth) Kütz. May to June. Common in May.

Division Euglenophyta

Class Euglenophyceae

** *Euglena acus* Ehrenberg

Euglena deses Ehrenberg

Euglena elastica Prescott

Euglena elongata Schewickoff

Euglena minuta Prescott

Euglena polymorpha Dangeard

Euglena sanguinea Ehrenberg

Euglena triperis (Duj.) Klebs

These species of Euglena were found at some time during the course of study. Their numbers were extremely low and no pulse was observed for any of them.

**Phacus acuminatus* Stokes

Phacus curvicauda (Ehrenb.) Dujardin

Phacus pleuronecta (Muell.) Dujardin

Phacus pyrum (Ehrenb.) Stein

Phacus tortus (Lemm.) Skvortzow

These species of Phacus, when considered together, were most abundant during the August to September period. Their numbers were very small and often only two or three cells were found throughout the entire study period.

**Phacus nordstedtii* Lemmermann June to June. This species was found every month of the study with the exception of February. It was most abundant in fall and spring.

**Lepocinclis acuta* Prescott May. Rare. Several cells were found on May 12, 1966.

***Trachelomonas armata* (Ehrenb.) Stein

Trachelomonas dybowskii Drezepolski

Trachelomonas erecta Skvortzow

Trachelomonas hispida (Perty) Stein

Trachelomonas acanthostoma (Stokes) Deflandre

Trachelomonas woyeickii Koczwara

All species found in the periods Sept. to Dec.; March to June. Abundant in late fall and early spring.

Division Pyrrophyta

Class Dinophyceae

Ceratium hirundinella (O.F. Muell.) Dujardin. June to Sept. Occasional to common. No real peak observed. Cells that were found were non-motile and discolored.

Glenodinium kulczynskii (Wolosz) Schiller June to Sept. Rare.

**Peridinium gatunense* Nygaard May to Oct. Occasional to common. Showed highest numbers in spring.

Class Cryptophyceae

Chroomonas nordstedtii Hansgirg Oct. Rare. Several cells found in the month of October.

**Cryptomonas erosa* Ehrenberg Nov. to March. Abundant during the winter with largest numbers in March.

Division Cyanophyta

Class Myxophyceae

**Anabaena circinalis* Rabenhorst July to Aug. Abundant with a peak on Aug. 4. This peak was accompanied by a marked reduction in numbers of Anabaena flos-aquae.

**Anabaena flos-aquae* (Lynb.) de Brébisson June to Oct. Abundant. Reached three small maxima: one in June, another in lake July, and the third in early September.

**Anabaena macrospora* Klebahn August to September. Abundant. Reached a peak when the above two species of Anabaena were reduced in numbers.

Arthrospira jenneri (Kuetz.) Stizenberger July to November. Occasionally found in bottom waters.

Aphanocapsa pulchra (Kuetz.) Rabenhorst July to Sept. Occasional.

Chroococcus limneticus Lemmermann August. Rare.

Dactylococcopsis fascicularis Lemmermann July to March. Rarely found, however, when lake and ice water were cultured, often appeared as the dominant alga.

Gleocapsa aeruginosa (Carm.) Kuetzing June to August. Rare.

**Merismopedia tenuissima* Lemmermann May to Oct. Largest numbers obtained in late Aug. in bottom waters.

Microcystis incerta Lemmermann July to August. Rare

Nostoc commune Vaucher July to Oct. Common. Colonies becoming detached from substrate at any time of the year.

Oscillatoria limnetica	Lemmermann	June to Aug.	Planktonic trichomes found abundantly in spring and mid-summer.
Oscillatoria minima	Gicklhorn	July to Aug.	Rare.
Oscillatoria tenuis	C.A. Agardh	July to Sept.	Rare.
Phormidium autumnale	(C.A. Ag.) Gomont	July to Sept.	Rare.
Spirulina major	Kuetzing	July to Oct.	Occasional.
Spirulina nordstedtii	Gomont	July to Oct.	Occasional.
Tolyothrix sp.		September.	Rare.

* Species treated quantitatively.

** Genus was considered as a group in the quantitative analyses.

Seasonal Succession:

June (II) 1965: The dominant groups of phytoplankton in Muir Lake during the month of June 1965 were the Chrysophyceae and the Cyanophyta. *Anabaena flos-aquae* dominated the Cyanophyta and the entire phytoplankton community with 2,693 cells/ml. The sub-dominant alga of the late June phytoplankton community was *Dinobryon sertularia* with 645 cells/ml, which made this species the dominant Chrysophyte. The subordinate category was made up of a few members from each algal group. Here were included the diatom *Asterionella formosa*; the green algae *Coelastrum microporum*, *Pediastrum boryanum*, and *Scenedesmus spp;* the Chrysophytes *Dinobryon divergens* and *Mallomonas acaroides;* the dinoflagellates *Ceratium hirundinella* and *Peridinium gatunense;* several *Euglena* species; and the blue-green alga *Merismopedia tenuissima*.

The dominant alga, *Anabaena flos-aquae*, decreased in numbers from 2,593 cells/ml to 1,308 cells/ml by the end of the month, but, still remained dominant. The sub-dominant *Dinobryon sertularia* decreased in numbers sharply (554 to 61 cells/ml) by the end of the month to become a subordinate species. The green alga, *Coelastrum microporum*, increased from 100 cells/ml on June 23 to 418 cells/ml on June 30 to replace *Dinobryon sertularia* as the sub-dominant species of the late June phytoplankton community.

July (I): The total phytoplankton crop, excluding the Chrysophyceae, declined in numbers of cells by early July (June 30=141 units per ml, July 7=47 units per ml). By mid-July, however, many algae increased markedly in numbers as several species decreased. A sharp decline in the

numbers of the blue-greens *Anabaena flos-aquae* (554 to 350 cells/ml) and *Merismopedia tenuissima* (684 to 61 cells/ml) by mid-July was accompanied by a sharp increase in the numbers of the green algae *Scenedesmus dimorphus* (0 to 40 cells/ml), *S. quadricauda* (34 to 188 cells/ml), *Pediastrum duplex* (0 to 68 cells/ml), *P. boryanum* (0 to 34 cells/ml) and *Cosmarium punctulatum* (0 to 3 cells/ml). Increases were also observed in the diatom *Asterionella formosa* population and the dinoflagellates *Ceratium hirundinella* and *Peridinium gatunense* but these were less striking than the increases in the green algae. *Anabaena flos-aquae* was the dominant alga during the first two weeks in July.

(II) Shortly after mid-July, a large increase in the Chrysophyte *Mallomonas acaroides* (65 to 1,363 cells/ml), particularly at a depth of five meters at station 1, made this alga the dominant. The blue-green *Anabaena flos-aquae* was the sub-dominant together with *Anabaena circinalis* which appeared for the first time in concentrations of 388 cells/ml. Both of these blue-green algae had increased over the June (II) levels, and as this occurred, the green algae *Scenedesmus* and *Pediastrum* decreased markedly (*Scenedesmus:* 173 to 11 cells/ml, *Pediastrum;* 102 to 0 cells/ml). The diatom *Asterionella formosa* and the Chrysophyte *Dinobryon divergens* declined following an earlier pulse in June. Near the end of July, the Euglenophyte *Phacus nordstedtii* was found to increase noticeably (from the July 21 reading of 0 to the July 28 reading of 24 cells/ml).

August (I): During the first two weeks in August, *Anabaena circinalis* increased beyond the numbers of any other alga, (390 to 912 cells/ml),

and as a result, became the dominant species. *Anabaena flos-aquae* became the sub-dominant alga (553 cells/ml). Once again it was noted that as these two blue-green species increased, the green algae *Scenedesmus quadricauda*, *S. dimorphus*, *Pediastrum duplex* and *P. boryanum* decreased in numbers. During the same period of early August, *Mallomonas acaroides* decreased from 1,363 to 225 cells/ml as *Ceratium hirundinella* increased from 0 to 6 cells/ml. By mid-August a new species of *Anabaena* appeared. *Anabaena macrospora* was present in numbers of 400 cells/ml, and at the same time the numbers of *Anabaena circinalis* dropped from 912 cells/ml to the level of 155 cells/ml. *Anabaena flos-aquae* decreased from a count of 553 cells/ml on August 4 to a count of 106 cells/ml on August 11. As the numbers of *Anabaena circinalis* and *Anabaena flos-aquae* decreased, again the numbers of green algae increased. Included with the green algae *Scenedesmus* and *Pediastrum* that were found to increase as the blue-green algae decreased were *Ankistrodesmus falcatus*, *Cosmarium punctulatum*; the euglenoid *Phacus nordstedtii*, and the dinoflagellate *Peridinium gatunense*.

(II) The maximum segregation of phytoplankton species, based on what may be called the pro-blue-green element and the anti-blue-green element, was exhibited on August 18. On this date the blue-green algae *Anabaena circinalis*, *A. macrospora*, *A. flos-aquae*, and *Merismopedia tenuissima* increased sharply (155 to 390, 350 to 944, 106 to 195, and 79 to 2,267 cells/ml respectively) to dominate the entire phytoplankton community. At the same time, all other phytoplankton species reacted either in a positive or negative fashion towards this increase in the numbers of Cyanophytes. Those species that increased were regarded as pro-blue-

green elements while those species that decreased sharply were regarded as anti-blue-green elements. The species regarded as pro-blue-green were *Scenedesmus bijuga*, *Ceratium hirundinella*, *Staurastrum curvatum* var. *paradoxum*, *Euglena spp.* and *Phacus nordstedtii* (with increases of 0 to 6, 0 to 4, 0 to 3, 3 to 10, and 6 to 10 cells/ml respectively). The algae considered anti-blue-green included *Peridinium gatunense*, *Scenedesmus dimorphus*, *S. quadricauda*, *Asterionella formosa*, *Dinobryon sertularia*, *Ankistrodesmus falcatus* and *Mallomonas acaroides* (with decreases of 3 to 1, 35 to 11, 151 to 16, 9 to 0, 35 to 0, 55 to 47, and 51 to 1 cells/ml respectively). By the end of August, however, this separation into two distinct elements became somewhat obscured. *Anabaena circinalis* decreased in numbers to become sub-dominant to *Anabaena flos-aquae* and *Anabaena macrospora* , which, as codominants, attained large numbers. As the codominant blue-greens increased, several species of the anti-blue-green element of August 18, also increased. The species that increased by the end of August included *Ankistrodesmus falcatus*, *Coelastrum microporum*,and *Pediastrum spp.* as well as all the pro-blue-green elements. In general, by the end of August, the majority of the plankton algae in Muir Lake had increased considerably from the mid-August numbers.

The blue-green algae increased tremendously during the month of August as the Chrysophyceae and diatoms decreased. A small increase in the amount of green algae was noted while the Pyrrophytes and flagellates remained constant.

September (I): By the first week in September, *Anabaena flos-aquae* increased from 716 to 1,335 cells/ml, while all other blue-green algae

decreased. As a result, *Anabaena flos-aquae* became the dominant alga. The anti-blue-green elements which decreased with the increase in *Anabaena flos-aquae* included *Scenedesmus dimorphus*, *S. quadricauda*, *Cerasterias staurasteroides*, *Coelastrum macroporum* and *Pediastrum spp.* On the other hand, increases were recorded for *Ankistrodesmus falcatus*, *Asterionella formosa* and *Peridinium gatunense*. By the second week of September, *Anabaena flos-aquae* , although still dominant, decreased in numbers to 586 cells/ml. *Asterionella formosa*, which had increased by the first week, increased further (3 to 7 cells/ml) together with *Dinobryon sertularia* (0 to 10 cells/ml). Mixed green species remained abundant and formed the sub-dominants of the plankton algae crop.

(II) The accelerated increase of green algae and flagellates led to their dominance by the latter part of the month. *Asterionella formosa* and *Dinobryon sertularia* increased slightly. The euglenoid, *Trachelomonas*, appeared for the first time in the phytoplankton flora in a concentration of 41 cells/ml and was largely responsible for the great increase in the Euglenophyta. The outstanding feature of the dynamics of Muir Lake's phytoplankton community in September was the decline of blue-green algae and acute increases in the Chlorophyta and green flagellates.

October (I): *Pediastrum boryanum* was the most abundant species of plankton algae in early October. The flagellates *Phacus* and *Trachelomonas* increased greatly over the late September crop (4 to 25, and 6 to 26 cells/ml repectively).

(II) October 17 showed a remarkable change in species composition of the phytoplankton community in Muir Lake. Three of the most important species appeared for the first time: *Uroglenopsis americana, Synura uvella* and *Synedra ulna*. *Uroglenopsis americana* was the dominant alga at 1,300 cells/ml. *Synedra ulna* was the sub-dominant alga with 94 cells/ml. Many species which appeared in large numbers at the begining of the month disappeared completely or were reduced to very low numbers. For example, *Pediastrum boryanum* was reduced to nil from the October 1 count of 615 cells/ml, and *Scenedesmus dimorphus* was reduced to 29 cells/ml. Of the species that were found on October 1, only *Lagerheimia quadriseta* and *Asterionella formosa* increased in numbers (from 7 to 18, and from 3 to 21 cells/ml respectively).

The month of October showed an increase in the numbers of Euglenophytes (36 units/ml from 16 units/ml in September), accompanied by a conspicuous increase in the number of diatoms (59 units/ml from the 0.75 units/ml in September). Further reductions of blue-green algae (from the September reading of 23 units/ml to 17 units/ml) and the Chrysophyceae (from the September reading of 19 units/ml to 8 units/ml) occurred. The Chlorophyta increased to 101 units/ml from the September average of 64 units/ml.

November: Autumn maxima were observed for the diatom *Asterionella formosa* (143 cells/ml), the unicellular green alga *Lagerheimia quadriseta* (146 cells/ml) and the colonial Chrysophyte *Synura uvella* (147 cells/ml). Increases were also recorded for the green algae *Scenedesmus spp.* and *Ankistrodesmus falcatus*. *Synura uvella, Asterionella formosa* and

Lagerheimia quadriseta codominated the community, while *Scenedesmus spp.* were the sub-dominant species. The Euglenophyta were greatly reduced in numbers to 18 units/ml from the October level of 36 units/ml while the blue-green algae disappeared entirely. The green algae increased markedly to 174 units/ml from the October count of 101 units/ml. *Cryptomonas erosa*, a member of the Pyrrophyta, also increased sharply from the October count of 0 to the November count of 26 units/ml.

December: A distinct early winter phytoplankton flora developed. *Trachelomonas, Euglena* and *Synura,* common fall genera, disappeared entirely while others were severely reduced in numbers, for example, *Cryptomonas erosa* (26 to 6 cells/ml) and *Scenedesmus dimorphus* (41 to 13 cells/ml). Still others increased, particularly the green alga *Scenedesmus quadricauda* (45 to 88 cells/ml). New species appeared for the first time during the study. These were *Oocystis parva, Chlamydomonas globosa* and *Crucigenia tetrapedia* --all Chlorphytes. In general, all groups of algae decreased with the exception of the green algae which appeared for the first time and made up 84% of the total December phytoplankton crop.

February: The algal flora during the month of February was almost non-existent. All algae, but *Scenedesmus dimorphus,* decreased or disappeared. Of the species that remained, 79% were members of the Chlorophyta.

March: All of the phytoplankton groups increased in numbers of organisms during the month of March. *Cryptomonas erosa* (Pyrrophyta) increased to nearly 100 cells/ml (from the February reading of 2 cells/ml) to become

the dominant alga. The green algae *Chlamydomonas globosa* and *Scenedesmus quadricauda* became sub-dominant with 40 and 66 cells/ml respectively. The subordinate genera, *Synedra, Euglena, Phacus* and *Tetraëdron* increased slightly from the low numbers found in February.

Members of the Pyrrophyta appeared most frequently with reference to the percentage of the total phytoplankton. The diatoms increased in percentage of the total phytoplankton over the February levels while the Chlorophyta decreased. Although the Chlorophyta decreased in percentage of the total phytoplankton, many species within this group did show increases in number, however, these increases were slight compared to the increases within other groups.

May (I): In early May the spring phytoplankton flora returned to Muir Lake. Algae from all groups except the Cyanophyta were present and abundant. The green algae dominated the early May community of plankton algae which also showed sizeable gains in the diatoms *Asterionella formosa* (0 to 8 cells/ml) and *Synedra ulna* (27 to 51 cells/ml) and the Chrysophyte *Dinobryon sertularia* (0 to 133 cells/ml).

(II) By the end of May, *Dinobryon sertularia* gained in numbers (to 1,992 cells/ml) to become the dominant alga. The many green algae were approximately equal in numbers to the diatoms, the latter made up exclusively of *Synedra ulna* and *Asterionella formosa* . In general, the Chrysophyceae dominated the month's phytoplankton crop.

June (I): Dinobryon sertularia dominated the early June phytoplankton crop but decreased in numbers from the May 26 count of 1,991 cells/ml to the June 6 count of 1,226 cells/ml. *Dinobryon divergens* and the diatom *Synedra ulna* were sub-dominant with 296 and 222 cells/ml respectively. The blue-green alga *Anabaena flos-aquae* reappeared in small numbers (114 cells/ml) and at the same time a reduction in the numbers of the green alga *Scenedesmus dimorphus* (99 cells/ml on May 26 to 23 cells/ml on June 6) occurred.

(II) By the end of June, *Anabaena flos-aquae* once again became the dominant member of the phytoplankton community. When this happened, many species of green algae decreased, and some disappeared completely. The diatom *Asterionella formosa* reached a peak at this time (103 cells/ml) and was the sub-dominant alga.

In general, the blue-green algae dominated the phytoplankton community of Muir Lake during the month of June 1966.

Summary: The seasonal succession of the major groups of phytoplankton is shown in Figure 19, page 127. The calculated percentage distributions, based on averages of numbers of units per month, are given for each group in Table 23, page 128.

The Chrysophyceae was the major group of the phytoplankton community during the months of June and July 1965. In August, this group declined to 18.6% (of the total monthly phytoplankton composition) from 85.5% of the total July phytoplankton crop. A regular decline was

Figure 19. Percentage distribution and succession of the major groups of phytoplankton based on average monthly unit counts at station 1 in Muir Lake.

MUIR LAKE Station I.

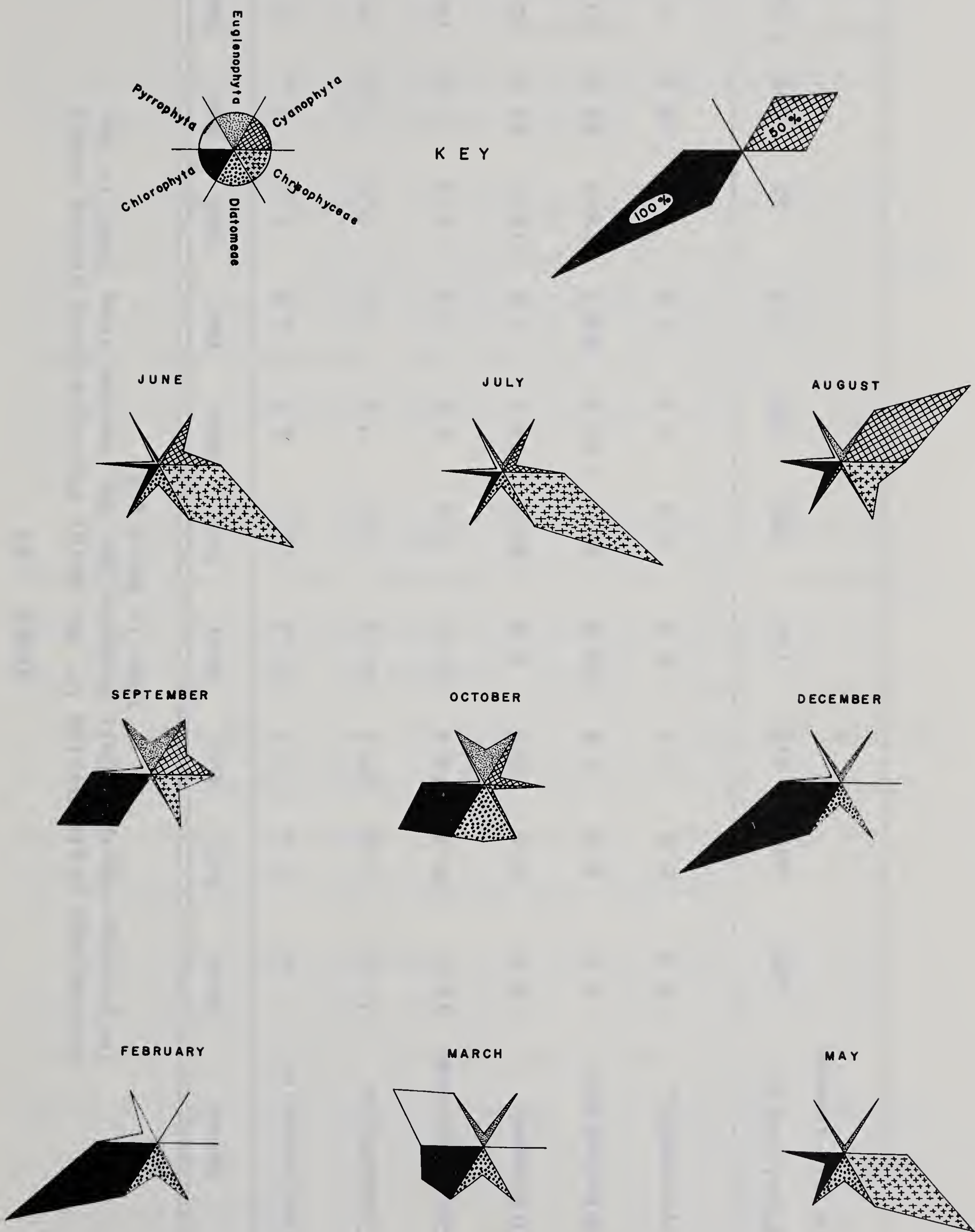

TABLE 23

Percentage Distribution Of The Major Phytoplankton Groups Based On Average Monthly Unit Numbers For The Period June 1965 to May 1966 In Muir Lake

Group	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Feb.	Mar.	May
Euglenophyta	.4	1.4	2.5	12.8	16.1	6.5	4.2	0.0	5.4	2.0
Cyanophyta	11.9	4.2	69.7	18.2	7.6	0.0	0.0	0.0	0.0	0.0
Chrysophyceae	74.1	85.5	18.6	15.1	3.6	2.9	0.0	0.0	0.0	72.6
Diatomeae	8.4	5.4	0.6	0.6	26.5	18.1	8.4	13.0	13.4	13.6
Chlorophyta	4.5	3.0	7.6	50.9	45.3	63.0	84.5	78.3	32.5	11.7
Pyrrophyta	0.4	0.4	1.0	2.4	0.9	9.4	2.8	8.7	48.8	0.4
Total Units Of All Groups	463	495	419	126	223	276	213	23	203	1,505

observed every month following August until a reading of zero percent of the total plankton algae crop was obtained for the month of February. The reappearance of the Chrysophyceae in May, 1966, was striking as it then formed 92.6% of the phytoplankton community.

The Cyanophyta increased in percentage of the total monthly phytoplankton crop until the largest percentage of blue-greens occurred during August. By this month, 69.7% of the total phytoplankton crop was composed of blue-green algae. From this point, the percentage of Cyanophytes decreased and reached zero by November 1, 1965 and June 6, 1966.

The dinoflagellates (Pyrrophyta) were observed throughout the May to October period in small percentages of the total monthly phytoplankton community. No monthly percentage of dinoflagellates exceeded 2.4% of the total. *Cryptomonas erosa* (another Pyrrophyte) appeared during the late fall and winter months. This alga was found in quantities sufficient to raise the monthly percentage of the Pyrrophyta to 48.8% of the total phytoplankton community during the month of March. By May, this alga had disappeared from the entire phytoplankton community.

The Diatomeae declined steadily from 8.4% in June to 0.6% of the total phytoplankton community in September. A sharp increase in the diatoms took place during October when 26.5% of the total monthly phytoplankton crop was composed of diatoms. From this point, a regular decrease occurred until the late winter and spring of 1966 when a slight increase was recorded.

The Euglenophyta showed highest percentages in September and October (12.8% and 16.1% of the total monthly phytoplankton crop respectively). February was the only month that showed a complete absence of the flagellates.

Small percentages (such as 4.5%) of the June to September total monthly phytoplankton communities were made up of the Chlorophyta. During September, and through until May, when other groups declined in numbers, the green algae increased in percentage composition of the plankton algae crop.

2. Hastings Lake

Species Composition

Presence List Of Phytoplankton With Notes On Their Time Of Occurrence And Relative Abundance

Division Chlorophyta

Class Chlorophyceae

Order Volvocales

**Chlamydomonas globosa* Snow Dec. to May. Abundant.

Gonium sociale (Duj.) Warming May, 1966. Rare.

**Pandorina morum* (Muell.) Borg. May; July to Dec. Occasional in summer, most abundant in Sept. to Oct.

Order Tetrasporales

Gleocystis sp. October. Rare.

Sphearocystis schroeteri Chodat October. Occasional.

Order Chlorococcales

**Actinastrum hantzschii* Lagerheim July to Aug.; Sept. to Oct. Abundant. Pulse in Sept. to Oct. was very distinct. Smaller spring pulse.

**Ankistrodesmus falcatus* (Corda) Ralfs Dec. to May. Rare. Greatest numbers in March.

Botryococcus sudeticus Lemmermann Nov. to Dec.; March. Occasional. Common in fall and early spring.

Cerasterias staurasteroides West & West June. Rare.

**Coelastrum microporum* Naegeli June to July; Oct.; May to June. Large pulse in spring. Occasional in autumn.

Crucigenia quadrata Morren Dec. to May. Rare to occasional.

Kirchneriella contorta (Schmidle) Bohlin Dec. to May. Occasional.

**Lagerheimia quadriseta* (Lemm.) G.M. Smith June to Oct. Rare.

**Oocystis parva* West & West Oct. to Dec.; March to June. Very abundant in the Oct. to Dec. pulse and the March to June pulse.

**Pediastrum boryanum* (Turp.) Meneghini June to June. A pulse in spring 1965. Another increase in March 1966.

**Pediastrum duplex* Meyer June to June. Distinct spring pulse. Occasional during the remainder of the year.

Pediastrum duplex var. *reticulatum* Lagerheim June to June. Occasional. Also showed a spring pulse, but very small.

Pediastrum tetras (Ehrenb.) Ralfs March. Rare.

Pediastrum obtusum Lucks June. Rare.

Planktosphaeria gelatinosa G.M. Smith Oct. Rare.

Quadrigula lacustris (Chod) G.M. Smith March. Occasional.

**Scenedesmus bernardii* G.M. Smith July. Occasional during this period.

**Scenedesmus bijuga* (Turp.) Lagerheim May to June. Occasional.

**Scenedesmus dimorphus* (Turp.) Kuetzing June to June. Many pulses of short duration.

**Scenedesmus quadricauda* (Turp.) de Brébisson June to June. Many pulses throughout the study period. Largest in June, mid-July, Aug. and Sept.

**Schroederia judayi* G.M. Smith July; Oct. to Dec.; March to June. Pulse in late autumn and early spring.

Schroederia setigera (Schroed.) Lemmermann July. Rare.

**Selenastrum gracile* Reinsch Oct. to Dec.; May. Fall and spring pulses.

Tetraëdron arthrodesmiforme (G.S. West) Wolsyńska Oct. Rare.

Tetraëdron minimum (A. Braun) Hansgirg Oct.; May. Occasional.

Tetraëdron trigonum (Naeg.) Hansgirg Oct. Rare.

Trochiscia zachariasii Lemmermann Dec. to May. Rare.

Order Desmidiales

Closterium acutum (Lyngbye) Brébisson Sept. to Oct.; May to June. Large peak in Sept. to Oct. period. Small pulse in spring.

Cosmarium punctulatum Brébisson June to June. Small pulse in fall. Beginning of pulse in June, 1966.

Staurastrum curvatum var. *paradoxum* June to June. Occasional pulse in Sept. to Oct. period.

Division Chrysophyta

Class Chrysophyceae

Harpochytrium hyalothecae Lagerheim May. Rare.

Mallomonas acaroides Perty June to Sept. A small pulse was found in July.

Tribonema minus (Wille) Hazen Aug. to Oct. Rare at station 1 and 3. Dominant alga during the Aug. to Oct. period in station 2, reaching more than 25,000 cells per milliliter of water.

Class Bacillariophyceae

Fragillaria crotenensis Kitton Aug. to Oct. Occasional.

**Stephanodiscus astraea* (Ehrenberg) Grunow June to June. Most persistant alga in Hastings Lake. Could be found at any time of the year with only small numbers in the winter.

Stephanodiscus hantzschii Grunow May to June; Oct. Common during spring and autumn following turnover.

Synedra ulna (Nitzsch) Ehrenberg Oct. Rare.

**Tabellaria fenestrata* var. *asterionelloides* (Lynb.) Kutz June to Aug.; Sept. Pulse in spring 1965, occasional during July to Sept. period.

Division Euglenophyta

Class Euglenophyceae

Euglena elongata Schewiakoff

Euglena minuta Prescott

**Phacus acuminatus* Stokes

Phacus orbicularis var. *caudatus* Skvortzow

Phacus nordstedtii Lemmermann

Lepocinclis acuta Prescott

Trachelomonas dybowskii Drezopolski

Trachelomonas acanthostoma (Stokes) Delfondre

All members of the Euglenophyta found in Hastings Lake appeared in the spring and autumn periods only (May and October).

Division Pyrrophyta

Class Dinophyceae

**Ceratium hirundinella* (O.F. Muell.) Dujardin June to Oct. One pulse in mid-August.

Class Cryptophyceae

**Cryptomonas erosa* Ehrenberg Feb. Rare.

Division Cyanophyta

Class Myxophyceae

**Anabaena circinalis* Rabenhorst August. Occasional to common.

**Anabaena flos-aquae* (Lynb.) de Brébisson June to Oct. Pulse found during July to Aug. period.

Anabaena spiroides var. *crassa* Lemmermann Aug. to Sept. Occasional.

Aphanizomenon flos-aquae (L.) Ralfs July to Sept. Part of Cyanophyte bloom in mid-summer. Abundant.

**Chroococcus limneticus* Lemmermann Aug. to Oct. Two pulses: one in fall, second in spring.

**Coelosphaerium naegelianum* Unger Aug. to Oct.; May to June. Large pulse in Aug. to Sept. period.

Dactylococcopsis fasicularis Lemmermann Dec. to March. Rare.

Gleocapsa aeruginosa (Corm.) Kuetzing June to Oct. Rare.

Merismopedia elegans A. Braun July. Occasional.

**Merismopedia glauca* (Ehrenb.) Naegeli June to Aug. Pulse in late June and early July.

Microcystis aeruginosa Kuetz July to Sept. Dominant alga in mid-summer bloom.

Oscillatoria sp. August. Rare.

Phormidium favosum (Borg.) Gomont October. Rare.

* Species treated quantitatively.

Seasonal Succession

June (I): The early June phytoplankton flora in Hastings Lake was dominated by the green alga, *Pediastrum duplex*, with 2,198 cells/ml. The sub-dominant species were: the green algae, *Actinastrum hantzschii* (315 cells/ml), *Scenedesmus dimorphus* (351 cells/ml), and *S. quadricauda* (452 cells/ml); the blue-green alga, *Merismopedia glauca* (424 cells/ml), and the diatoms, *Tabellaria fenestrata* var. *asterionelloides* (381 cells/ml) and *Stephanodiscus astraea* (325 cells/ml).

(II): *Coelastrum microporum* (Chlorophyte) increased from the June 9 count of 535 cells/ml to the June 24 count of 1,864 cells/ml to become the dominant species in late June.* The phytoplankton floras at station 1 and 2 were identical in species composition during June, but the numbers of most species were higher at station 2. The sub-dominant phytoplankton species in late June were the green alga, *Pediastrum spp.* (1,225 cells/ml) and the blue-green alga, *Anabaena flos-aquae* (1,117 cells/ml). The subordinate algae were *Tabellaria fenestrata* var. *asterionelloides* (491 cells/ml), *Stephanodiscus astraea* (197 cells/ml), and *Scenedesmus spp.* (179 cells/ml).

The percentage of the green algae (based on units of the total phytoplankton crop) was higher than any other single group of algae in

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* The figures used were based on station 1 data. Whenever the phytoplankton at the three stations were found to differ markedly in the number of cells or units of a species, the station number is indicated; otherwise the figures from station 1 are used and regarded as characteristic of the phytoplankton of the entire lake.

Hastings Lake during the month of June. The blue-green algae appeared with a higher frequency at station 2 than at station 1 (32.4% of the total phytoplankton community at station 2 and 7.8% of the total plankton algae crop at station 1), while the diatoms appeared with greater frequency at station 1 than at station 2 (42.5% at station 1 and 5.4% at station 2).

July (I): All of the major groups of plankton algae, except the blue-green species, decreased sharply during early July. The green alga, *Pediastrum boryanum*, was the dominant species on July 1 with 5,813 cells/ml. The blue-green algae *Anabaena flos-aquae* and *Merismopedia glauca* increased in numbers from 1,117 and 131 cells/ml on June 24 to 2,679 and 1,313 cells/ml on July 1, respectively, to become the subdominant algae. Those stations which showed large increases in the blue-green algae, especially in the two species given above, showed large decreases in the majority of green algae and diatoms. For example, as *Merismopedia glauca* increased from 131 cells/ml to 1,313 cells/ml, the green alga *Scenedesmus dimorphus* declined from 106 cells/ml to 9 cells/ml during the period June 24 to July 1.

(II): By July 15, all the algae increased in numbers. The diatom, *Stephanodiscus astraea*, showed the largest increase, from the July 8 count of 461 cells/ml to the July 15 count of 971 cells/ml, to become the dominant alga. The blue-green species formed the subdominant component of the phytoplankton community. By July 22, the majority of phytoplankton species decreased while sharp increases were noted for the blue-green alga *Anabaena flos-aquae* (6,293 to 23,060 cells/ml); the diatom *Tabellaria*

fenestrata var. *asterionelloides* (65 to 117 cells/ml); the dinoflagellate *Ceratium hirundinella* (1 to 13 cells/ml); and the green algae *Pediastrum boryanum* (2,881 to 16,209 cells/ml), *Pediastrum duplex* (431 to 472 cells/ml), *Pandorina morum* (173 to 301 cells/ml) and *Staurastrum curvatum* var. *paradoxum* (9 to 17 cells/ml). The July 22 phytoplankton community was dominated by *Anabaena flos-aquae* and subdominated by *Pediastrum boryanum*. *Stephanodiscus astraea* also appeared in large numbers. By the end of July, the blue-green algae decreased slightly at station 1 and 3. *Anabaena flos-aquae* still remained dominant at all three stations. The large decrease of blue-greens (especially *Anabaena flos-aquae*-- 27,759 to 7,638 cells/ml) at station 2 was accompanied by an increase in *Scenedesmus spp.* (5 to 32 cells/ml).

In general, the Cyanophyta increased in frequency at both stations 1 and 2 during the month of July. The Chlorophyta decreased at both stations while the diatoms increased in percentage of the total number of units of phytoplankton over the June level. The Diatomeae appeared with the highest frequency of all the groups of phytoplankton at station 1 while the Cyanophyta appeared with highest frequency of all phytoplankton groups.

August (I): Generally, a considerable decrease in the numbers of most algae took place by August 5. The dominant alga, *Anabaena flos-aquae*, decreased most markedly from the July 29 level of 25,555 cells/ml to the August 5 level of 6,931 cells/ml. The diatom, *Stephanodiscus astraea*, decreased from 594 to 146 cells/ml. At the same time, slight increases

were noted for *Tabellaria fenestrata* var. *asterionelloides* (14 to 86 cells/ml), *Pandorina morum* (55 to 91 cells/ml) and *Anabaena circinalis* (0 to 160 cells/ml). By the second week of August, the dominant species at station 1 was *Anabaena flos-aquae* (3,808 cells/ml). *Anabaena circinalis* (342 cells/ml), *Coelosphaerium nagelianum* (1,386 cells/ml), *Ceratium hirundinella* (43 cells/ml) and *Stephanodiscus astraea* (479 cells/ml) subdominated the station 1 plankton algae community during the first two weeks of August.

The station 2 phytoplankton community was dominated by the blue-green alga *Anabaena flos-aquae*, with 22,456 cells/ml and subdominated by the filamentous Chrysophyceae, *Tribonema minus*, which appeared in concentrations of 9,534 cells/ml. The subdominant algae at station 2 were *Ceratium hirundinella* (174 cells/ml) and *Pediastrum spp.* (257 cells/ml).

(II): The greatest accumulation of phytoplankton in Hastings Lake during the entire course of the study was observed on August 19. By this date, a "bloom" (concentration of plankton algae sufficient to discolor the water or form a macroscopically conspicuous growth which can be likened to pea-soup) of *Microcystis aeruginosa* and *Aphanizomenon flos-aquae* had developed throughout the entire lake. These two blue-green species were not treated quantitatively, therefore no actual figures of cell numbers are available. Of the phytoplankton treated quantitatively, *Anabaena flos-aquae* dominated, with 44,457 cells/ml at station 1. At station 2, *Anabaena flos-aquae* decreased from 22,456 cells/ml to 19,323 cells/ml, but still remained dominant. Accompanying this decline in the numbers of *Anabaena flos-aquae* at station 2, was the increase in the green algae *Scenedesmus dimorphus* and *S. quadricauda* from 5 and 8 cells/ml

to 142 and 401 cells/ml respectively.

A marked discrepancy between station 1 and station 2 in their percentage distribution of major phytoplankton groups occurred during August. Station 1 showed an increase in the frequency of appearance of blue-green algal species over the July calculated percentage (28.1% to 38.1% of the total phytoplankton crop). A marked reduction in the Chlorophyta, from 18.6% in July to 3.6% of the total plankton algae crop in August, occurred at station 1. Station 2, however, showed an increase in the frequency of occurrence of the Chrysophyceae from the July figure of 0.8% of the total phytoplankton community to 46.8% in August. Meanwhile, the Chlorophyta and Cyanophyta decreased in the percentage of occurrence (from 29.7% to 4.7% and 49.2% to 29.8% of the total, respectively) at station 2.

September (I): Early September showed a phytoplankton flora at station 1 that was dominated by the diatom *Stephanodiscus astraea* (735 cells/ml) and the blue-green alga *Coelosphaerium nagelianum* (1,022 cells/ml). This flora was subdominated by *Tribonema minus* (463 cells/ml) and *Pediastrum spp.* (185 cells/ml). The phytoplankton at station 2 was dominated by *Tribonema minus* with 22,593 cells/ml and subdominated by *Coelosphaerium nagelianum* (3,233 cells/ml), *Stephanodiscus astraea* (466 cells/ml), *Pediastrum spp.* (615 cells/ml), and *Scenedesmus spp.* (332 cells/ml). By the second week of September, the blue-green algae either disappeared (*Chroococcus limneticus* from the September 2 count of 116 to the September 9 count of 1 cell /ml at station 2) or were

reduced in numbers markedly (*Anabaena flos-aquae* declined from the September 2 count of 299 to the September 9 count of 9 cells/ml).

(II): A summer to autumn phytoplankton species transition took place by late September as the blue-green algae decreased to nil or very low numbers (9 cells/ml) and the many green algae increased; for example, *Pandorina morum* increased from 146 to 292 cells/ml during the September 16 to September 24 period. *Stephanodiscus astraea* dominated the station 1 phytoplankton with 475 cells/ml. *Coelosphaerium nagelianum* with 876 cells/ml and *Pediastrum boryanum* with 390 cells/ml were the subdominants. At station 2, *Tribonema minus* declined to 11,457 cells/ml from the September 16 count of 17,271 cells/ml, but still remained dominant. *Stephanodiscus astraea* (439 cells/ml) and *Pediastrum boryanum* (873 cells/ml) were the subdominant species at station 2 in late September.

The outstanding feature of the group phytoplankton dynamics in Hastings Lake during the month of September was the rapid decline of the Cyanophyta (38.1% to 1.9% and 29.8% to 1.5% of the total phytoplankton community at stations 1 and 2 respectively). Almost as striking a change in the Diatomeae took place as this group increased greatly in frequency of occurrence over the August total phytoplankton crop.

October (I): The dominant alga at station 1 in early October was *Stephanodiscus astraea* (529 cells/ml) while the subdominant alga was *Pandorina morum* (511 cells/ml). The subordinate algae that either increased or appeared for the first time in the phytoplankton at station 1 were *Closterium acutum* (31 cells/ml), *Actinastrum hantzschii* (201 cells/ml),

Pediastrum duplex (185 cells/ml), *Schroederia judayi* (14 cells/ml), and *Staurastrum curvatum* var. *paradoxum* (12 cells/ml).

Pediastrum boryanum (873 cells/ml) and *Tribonema minus* (4,957 cells/ml) codominated the phytoplankton community at station 2. *Stephanodiscus astraea* (253 cells/ml) was the subdominant. *Chroococcus limneticus* (Cyanophyte) increased from the September 24 count of 11 to 39 cells/ml by October 2 while *Scenedesmus dimorphus* decreased in numbers from 114 to 69 cells/ml during the same period.

(II): By the end of October a distinctly different phytoplankton flora from the summer type developed. This autumn flora contained many green algae. New species that were not seen previously, such as *Oocystis parva* and *Selenastrum gracile*, appeared in concentrations of 224 and 228 cells/ml respectively. All of the green algae were approximately equal in numbers so that no one species dominated the community. Some of these species were *Pediastrum boryanum* (410 cells/ml), *Pediastrum duplex* (205 cells/ml), *Pandorina morum* (365 cells/ml) and *Stephanodiscus astraea* (375 cells/ml).

The Chlorophyta increased in percentage of the total units of all groups of phytoplankton from 7.4% to 33.5% at station 1 and from 9.5% during the month of September to 38.2% at station 2 during October. The Diatomeae was the leading group at station 1 (65.8% of the total phytoplankton) and appeared in equal numbers with the Chlorophyta at station 2 (38.1%).

December: The winter phytoplankton flora at station 1 was dominated by the green alga *Chlamydomonas globosa*, with 82 cells/ml. *Stephanodiscus astraea* was the dominant species at station 2, with 80 cells/ml. The subdominant alga at station 1 was *Stephanodiscus astraea*, with 57 cells/ml, while *Chlamydomonas globosa* was the subdominant of the winter phytoplankton community at station 2. The green algae that persisted through until the end of December at both stations were *Schroederia judayi*, *Selenastrum gracile*, *Oocystis parva*, *Scenedesmus quadricauda*, *S. dimorphus* and *Staurastrum curvatum* var. *paradoxum*. Not one of these Chlorophytes exceeded 30 cells/ml.

February: All of the phytoplankton species, except for three, found in Hastings Lake in December had disappeared by February 5. *Chlamydomonas globosa*, in concentrations of less than 30 cells/ml, persisted and was the dominant alga in February. The Pyrrophyte, *Cryptomonas erosa*, was found at very low concentrations (1 cell/ml at station 1, 2 cells/ml at station 2) together with *Stephanodiscus astraea* (1 cell/ml at station 1, 0 at station 2).

March: More activity and higher numbers of phytoplankton occurred under the ice cover in March than at any other time in the winter period. The diatom *Stephanodiscus astraea* disappeared from the upper 7 meters of water but appeared in large concentrations at a depth of 8 meters (1,342 cells/ml). The green algae *Pediastrum boryanum* (1,661 cells/ml) and *P. duplex* (1,100 cells/ml) were the codominants and the green algae *Chlamydomonas globosa* (130 cells/ml) and *Oocystis parva* (184 cells/ml)

were the subdominants.

During the month of March, the Chlorophyta formed 79.6% of the total phytoplankton crop at station 2, while the other 21.4% was made up by the Diatomeae. At station 1, the Chlorophyta made up 72.1% of the total plankton algae community, the Diatomeae 26.7%, and the Euglenophyta 1.2%.

May (I): *Pediastrum spp.*, with 410 cells/ml, dominated the early May phytoplankton flora. *Stephanodiscus astraea* and *Oocystis parva*, with 154 and 174 cells/ml respectively, were the subdominant algae.

(II): By late May *Oocystis parva* increased to 695 cells/ml to become the dominant species of algae. *Pediastrum boryanum* became the subdominant species with 616 cells/ml. Many other algae, all Chlorophytes, were abundant at this time, such as *Pediastrum duplex* (581 cells/ml), *Scenedesmus spp.* (456 cells/ml), *Coelastrum microporum* (228 cells/ml), *Selenastrum gracile* (285 cells/ml at station 2) and *Actinastrum hantzschii* (307 cells/ml at station 2).

In general, all the groups of algae increased in numbers. At station 1, the Diatomeae increased in percentage of the total units of the phytoplankton community while at station 2, the Chlorophytes increased in frequency of occurrence over the previous month as the Diatomeae decreased.

June (I): All of the Phytoplankton species, except the blue-green *Chroococcus limneticus*, decreased by early June. Certain species, such as *Actinastrum hantzschii* and *Scenedesmus dimorphus* disappeared entirely.

Oocystis parva remained as the dominant algae at both stations (433 cells/ml at station 1, 374 cells/ml at station 2). *Chroococcus limneticus* was the codominant alga with 155 cells/ml.

(II): *Coelastrum microporum* and *Pediastrum duplex* codominated (4,788 and 3,078 cells/ml respectively) the late June phytoplankton flora. *Anabaena glos-aquae* increased from nil to 1,853 cells/ml at station 2, *Merismopedia glauca* increased from nil to 1,094 cells/ml and *Ceratium hirundinella* increased from nil to 51 cells/ml at station 1.

The three major groups of algae in Hastings Lake: the Chlorophyta, Cyanophyta and the Diatomeae, were approximately equal in the percentage composition of the June phytoplankton community.

Summary: The percentage composition, by group, of the phytoplankton flora for stations 1 and 2 are shown in Tables 24 and 25, pages 149 and 151 respectively, and Figures 20 and 21, pages 148 and 150, respectively. The Cyanophyta formed the group with the highest frequency of occurrence of all the phytoplankton at station 1 in August and at station 2 in July. *Stephanodiscus astraea* and *Tabellaria fenestrata* var. *asterionelloides* were the only plankton diatoms found, and together appeared more frequently than any other group of plankton algae throughout the May to October period at station 1. These diatoms were less persistent at station 2 where the Chrysophyceae represented the group of highest frequency in the August to September period. The dinoflagellates reached their maximum in August at both stations. Euglenophytes at no time appeared in plentiful numbers but were most abundant in early spring and late autumn. The group that formed the largest percentage of the total winter phytoplankton was the Chlorophyta.

Figure 20. Percentage distribution and succession of the major groups of phytoplankton based on monthly average unit counts at station 1 in Hastings Lake.

HASTINGS LAKE Station 1.

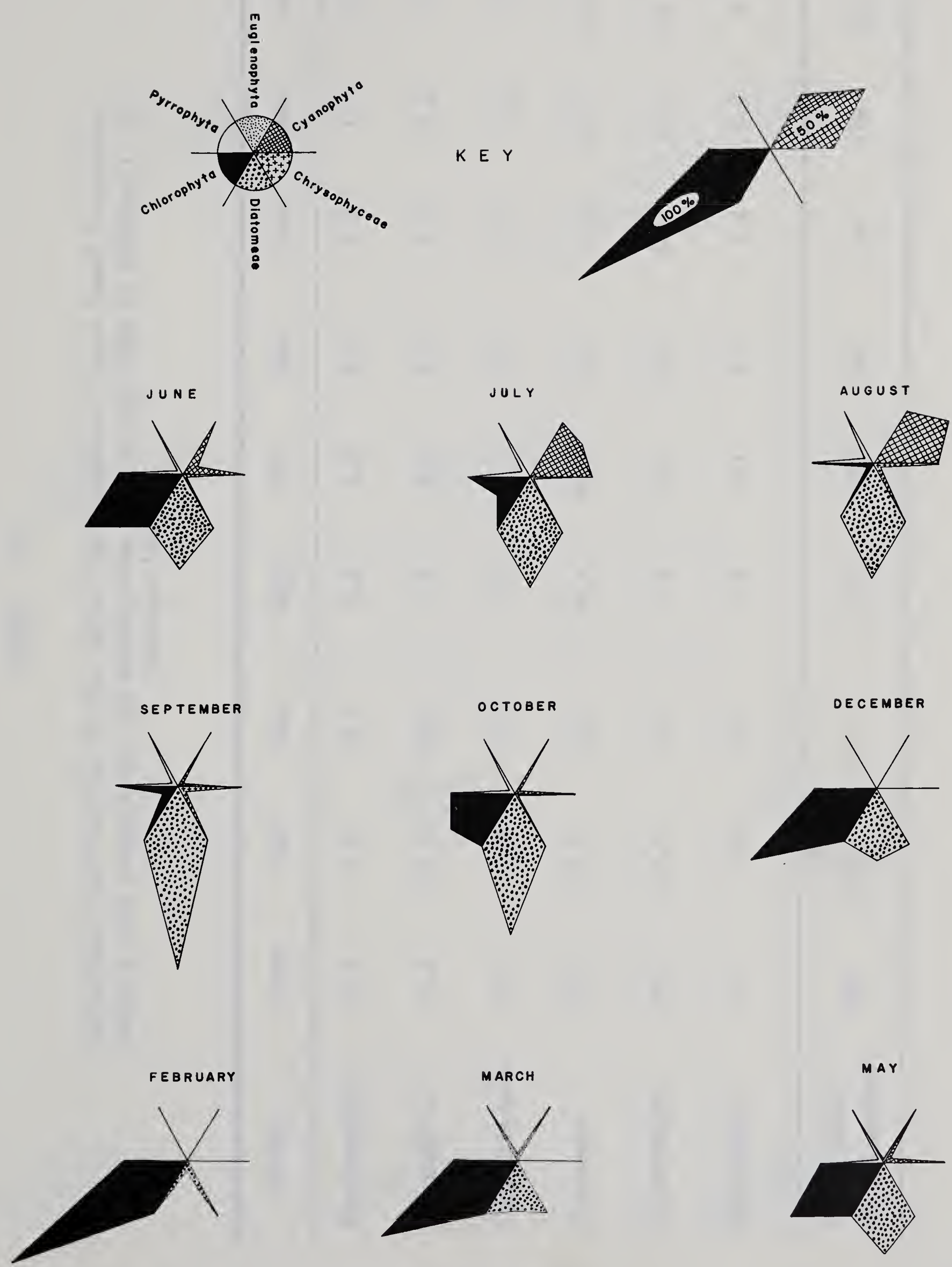


TABLE 24

Percentage Distribution Of The Major Phytoplankton Groups Based On Average Monthly Unit Numbers For The Period June 1965 to May 1966 At Station 1 In Hastings Lake

Group	June	July	Aug.	Sept.	Oct.	Dec.	Feb.	Mar.	May
Euglenophyta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.8
Cyanophyta	7.8	28.1	38.1	1.9	0.4	0.0	0.0	0.0	1.0
Chrysophyceae	0.1	0.3	2.0	2.8	0.3	0.0	0.0	0.0	0.0
Diatomeae	42.5	50.9	52.6	86.4	65.8	33.9	3.4	26.7	43.1
Chlorophyta	49.4	18.6	3.6	7.4	33.5	66.1	93.1	72.1	54.9
Pyrrophyta	0.1	1.8	3.7	1.4	0.1	0.0	3.4	0.0	0.2
Total Units Of All Groups	446	1,183	967	766	690	168	29	124	432

Figure 21. Percentage distribution and succession of the major groups of phytoplankton based on monthly average unit counts at station 2 in Hastings Lake.

HASTINGS LAKE Station 2.

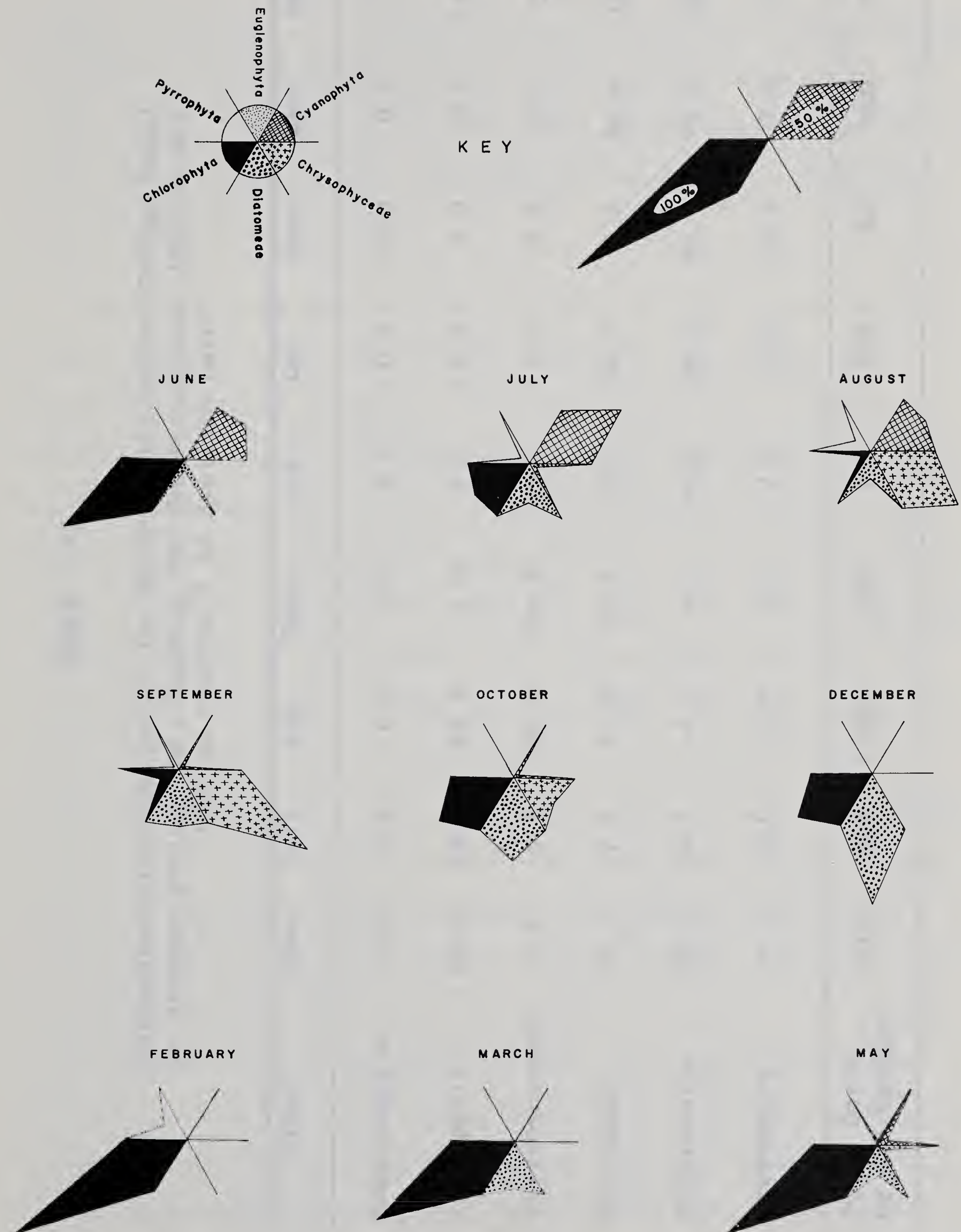


TABLE 25

Percentage Distribution Of The Major Phytoplankton Groups Based On Average Monthly Unit Numbers For The Period June 1965 to May 1966 At Station 2 In Hastings Lake

Group	June	July	Aug.	Sept.	Oct.	Dec.	Feb.	Mar.	May
Euglenophyta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
Cyanophyta	32.4	49.2	29.8	1.5	1.1	0.0	0.0	0.0	2.4
Chrysophyceae	0.0	0.8	46.8	68.2	22.7	0.0	0.0	0.0	2.2
Diatomeae	5.4	17.3	11.9	25.3	38.1	60.6	0.0	21.3	13.7
Chlorophyta	62.2	29.7	4.7	4.5	38.2	39.4	90.0	79.6	80.5
Pyrrophyta	0.0	3.0	6.8	0.5	0.0	0.0	10.0	0.0	0.0
Total Units Of All Groups	312	532	1,287	1,897	754	132	20	550	313

B. Regional Variation And Vertical Distribution

Regional Variation: A noteworthy regional variation in the quantitative distribution of phytoplankton occurred between stations within the two study lakes. This variation was more marked between stations 1 and 2, and 3 and 2 in Hastings Lake, than between stations 1 and 3 or between the two stations in Muir Lake.

The first discrepancy between the numbers of algae found at station 1 and station 2 in Muir Lake occurred on July 7. Many species that decreased in numbers at station 1 were found to increase in numbers at station 2. For example, *Merismopedia tenuissima* decreased from 89 cells/ml to 0 cells/ml (June 30 to July 7) at station 1 while at station 2, the numbers of cells of this species increased from 0 to 684 cells/ml during the same period. Similarly, the numbers of *Coelastrum microporum* decreased from 418 cells/ml to 0 at station 1 while their numbers rose from 0 to 114 cells/ml at station 2. Other species included in this variation were *Pediastrum boryanum* and *Staurastrum curvatum* var. *paradoxum*. This variation was exhibited on July 14 and July 21 but was much less prominent. On July 28, a distinct difference was noted between the numbers of algae at the two stations. A marked increase in the numbers of *Scenedesmus quadricauda* and *S. dimorphus* (13 to 81 cells/ml and 0 to 33 cells/ml respectively from July 21 to July 28) occurred at station 1. At station 2, the numbers of these two species of green algae remained unchanged. At this time, the blue-green alga *Anabaena flos-aquae* showed a difference in the numbers of cells at the two stations. Station 1 showed a decrease in the number of *Anabaena flos-aquae* cells (456 to 423 cells/ml) while

station 2 exhibited an increase (513 to 1,140 cells/ml). It was observed that when the blue-green algae (namely *Anabaena flos-aquae* and *Merismopedia tenuissima*) increased at either station in Muir Lake, the green algae (*Scenedesmus quadricauda* and *S. dimorphus*, in particular) decreased in numbers and that this correlation was strongly inverse. The regional, station-to-station variation in phytoplankton numbers at Muir Lake continued intermittently until the end of August, but was best developed during the month of July.

In Hastings Lake, station 2 differed greatly in the numbers of phytoplankton from both stations 1 and 3. Station 1 and station 3 were nearly identical in their quantitative composition of the different phytoplankters. Generally, with few exceptions, station 2 showed higher concentrations of all species of algae than did either station 1 or station 3 during the June to September period. Station 2 was generally quicker to react in fluctuations of algal numbers such as an earlier appearance and disappearance of Cyanophytes in summer and early fall respectively. On July 29, an increase in the numbers of the blue-green *Anabaena flos-aquae* occurred at station 1 (23,060 to 25,555 cells/ml from July 22 to July 29) while a decrease in numbers took place at station 2 (27,759 to 7,638 cells/ml). At the same time, station 1 showed a reduction in the number of green algae such as *Scenedesmus dimorphus* and *S. quadricauda* (from 68 to 3 cells/ml and 69 to 7 cells/ml respectively) as station 2 showed an increase in the numbers of these green algae (0 to 5 cells/ml and 5 to 28 cells/ml respectively). *Tribonema minus* appeared in such proportions at station 2 as to become

the dominant alga (maximum numbers of 25,628 cells/ml), while only small numbers occurred at stations 1 and 3 (maximum numbers of 644 and 721 cells/ml respectively). The diatom *Stephanodiscus astraea* always appeared more frequently at stations 1 and 3 than at station 2. If this occurrence of *Tribonema minus* and *Stephanodiscus astraea* (plus other more subtle differences) can be construed as representing the effects of very different ecological factors, then the areas in Hastings Lake around stations 1 and 3 are ecologically different from the area of station 2.

Vertical Distribution: Although vertical stratifications of plankton algae were short-lived because of considerable wind-induced mixing of the waters, certain species were found to vary in their vertical distribution within the two study lakes. Maximum stratification occurred during calm, sunny days in late spring and summer and during the winter period. On calm sunny days in summer the blue-green algae, because of the formation of pseudovacuoles in their cells, became buoyant and concentrated at the surface, as shown for *Anabaena flos-aquae* in Figure 22, page 155. *Ceratium hirundinella* also concentrated in the upper four meters of the water column, as shown by Figure 23, page 155. Included in the group of phytoplankton species which concentrated in the upper waters in late spring and summer were *Anabaena circinalis* (Muir and Hastings), *Anabaena macrospora* and *Dinobryon spp.* (Muir). During the winter period, *Chlamydomonas globosa* (Hastings and Muir) and *Lagerheimia quadriseta* (Muir) concentrated in the surface waters, immediately beneath the ice.

Figure 22. Vertical distribution of *Anabaena flos-aquae* based on monthly averages of cell numbers at station 1 in Hastings Lake.

Figure 23. Vertical distribution of *Ceratium hirundinella* based on monthly averages of cell numbers at station 1 in Hastings Lake.

Figure 22.

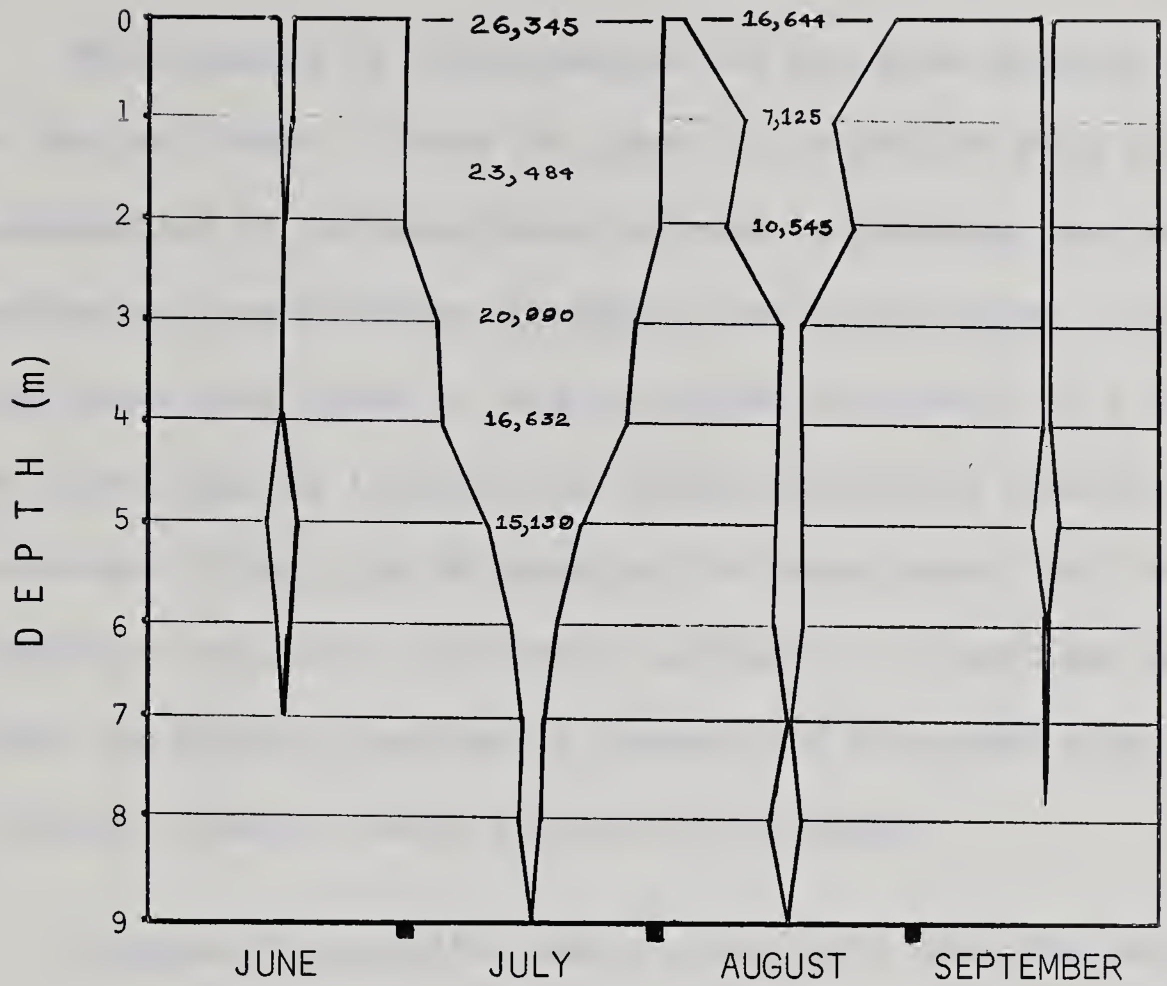
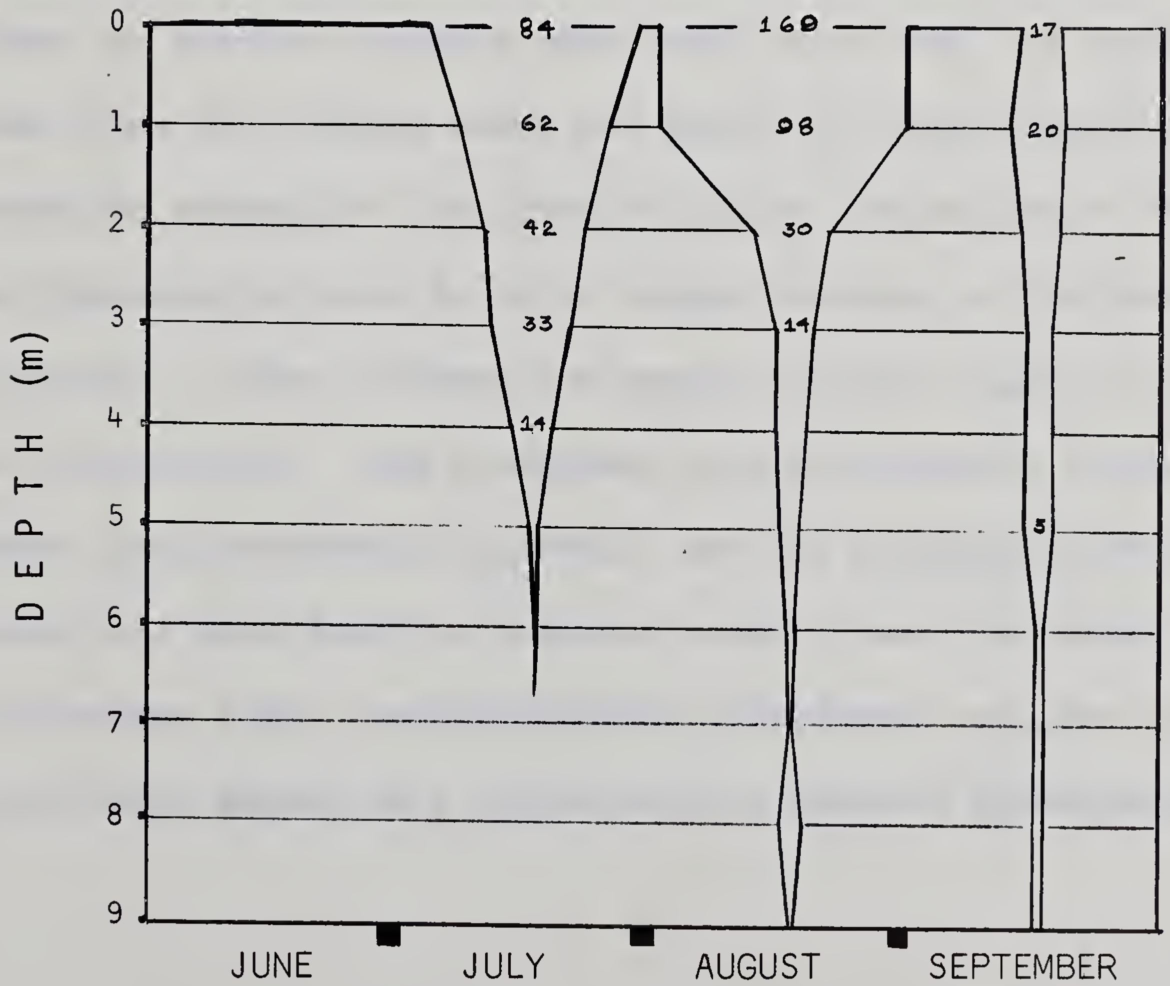


Figure 23.



Many species of phytoplankton did not show distinct stratifications in the two lakes. Figure 24, page 157, shows the more or less uniform distribution of *Stephanodiscus astraea* in Hastings Lake with this uniformity very distinct throughout the windy August to October period. Most algae were found to be distributed vertically in a uniform fashion, and these species included the diatom,*Tabellaria fenestrata* var. *asterionelloides*; the Chrysophyte,*Tribonema minus*; and the Chlorophytes *Pandorina morum* and *Actinastrum hantzschii* in Hastings Lake. In Muir Lake, the diatom,*Asterionella formosa* and the green alga, *Ankistrodesmus falcatus*, showed uniform vertical distribution.

Figures 25, page 159, and 26, page 159, show the vertical distributions of *Mallomonas acaroides* and *Trachelomonas spp.* in Muir Lake. These figures exemplify the vertical distributions of a number of algal species where the greatest numbers were found at or near the bottom. At the same time, the surface water was devoid of large numbers of these organisms except for the times following wind mixing of the waters. The Euglenophyta were found in largest numbers in the bottom waters of Muir Lake. These included the genera *Euglena*, *Phacus*, *Trachelomonas* and *Lepocinclis*. The blue-green alga, *Merismopedia tenuissima*, the green alga, *Scenedesmus dimorphus*, and the Chrysophyte, *Mallomonas acaroides*, were found in greatest numbers near the bottom of Muir Lake. In Hastings Lake, the Chlorophytes, *Scenedesmus spp.*, and *Cosmarium punctulatum*, showed this characteristic vertical distribution.

Figure 24. Vertical distribution of *Stephanodiscus astraea* based on monthly averages of cell numbers at station 1 in Hastings Lake.

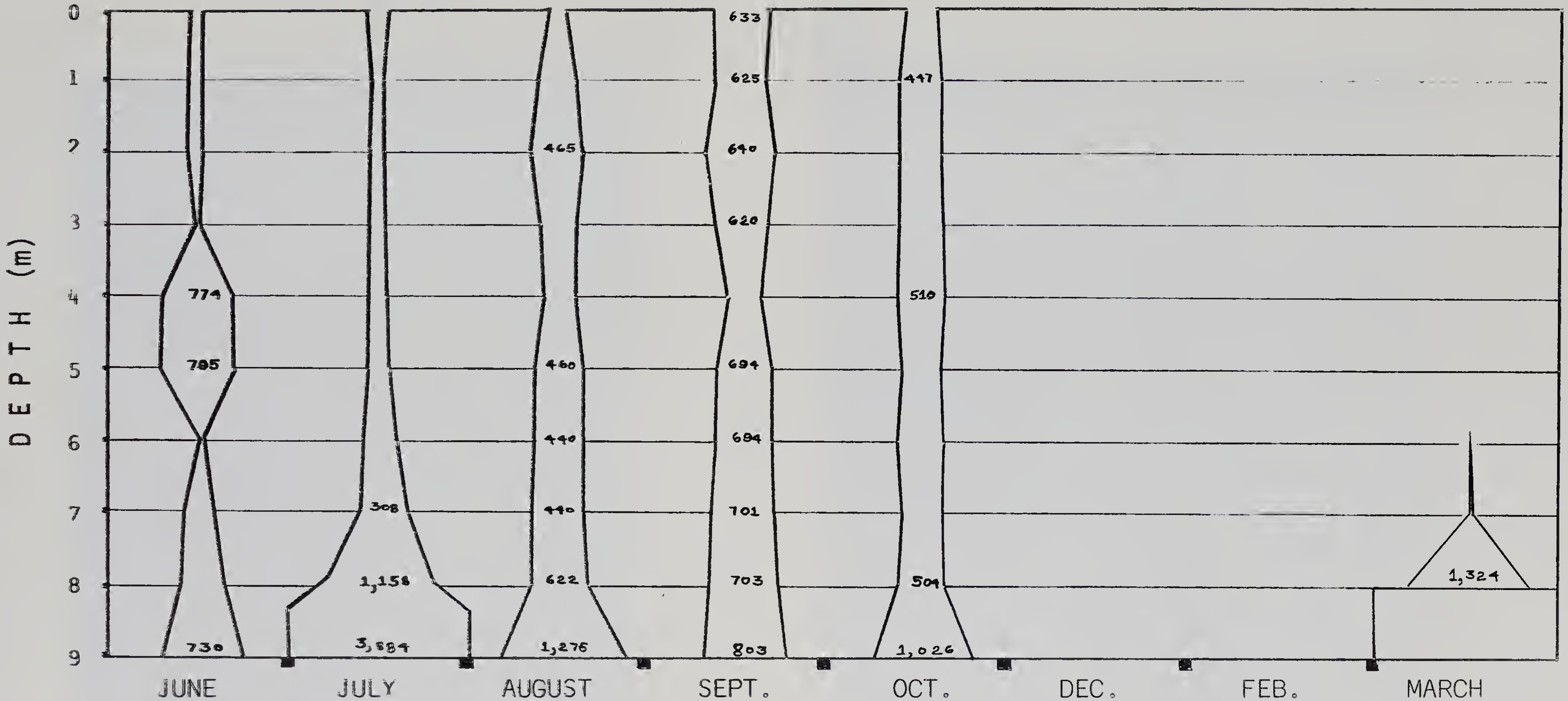

DEPTH (m)
0
1
2
3
4
5
6
7
8
9
774
785
730
308
1,158
3,884
465
460
440
440
622
1,276
633
625
640
620
694
684
701
703
803
447
510
509
1,026
1,324
JUNE
JULY
AUGUST
SEPT.
OCT.
DEC.
FEB.
MARCH

Plate 12. Hastings Lake on a calm day. Photograph shows the lake as seen from station 1, looking toward the north-west on May 25, 1966.

Plate 13. Hastings Lake on a windy day. Photograph shows the lake as seen from station 1, looking toward the north-east on October 17, 1965.

12.

13.

Figure 25. Vertical distribution of *Mallomonas acaroides* based on monthly averages of cell numbers at station 1 in Muir Lake.

Figure 26. Vertical distribution of *Trachelomonas spp.* based on monthly averages of cell numbers at station 1 in Muir Lake.

Figure 25.

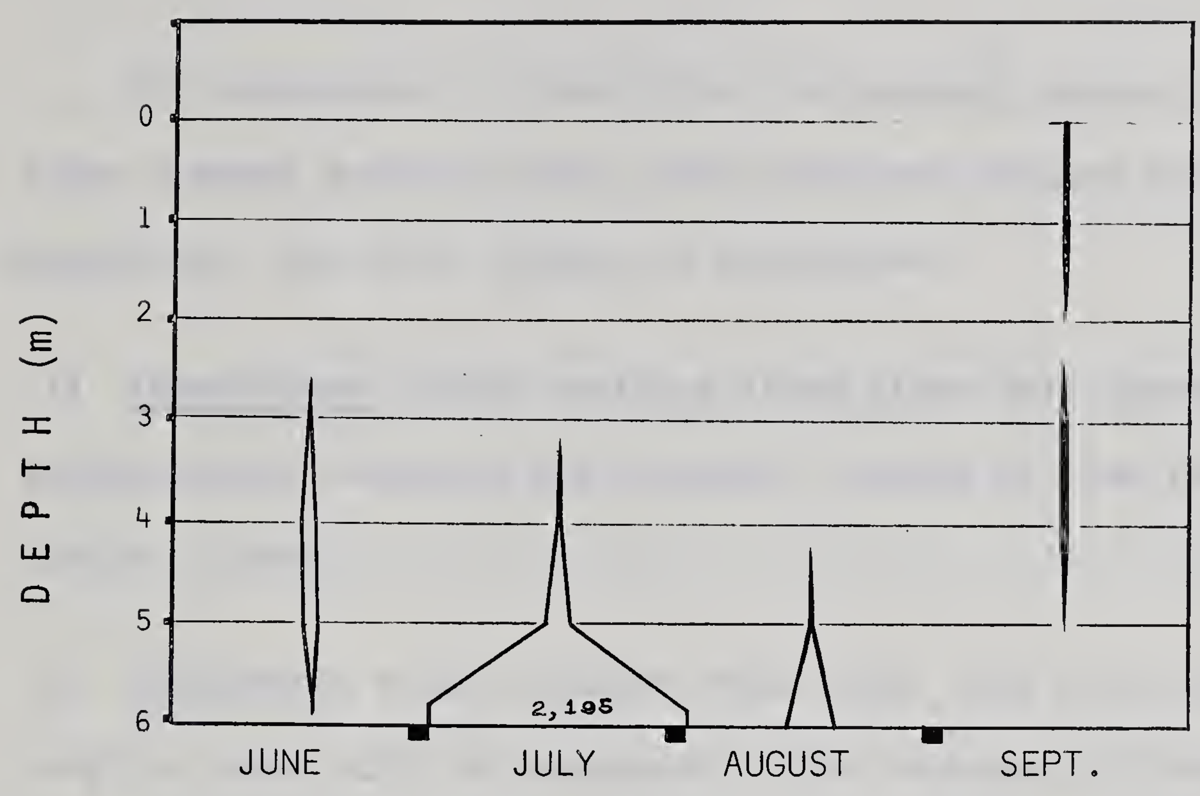
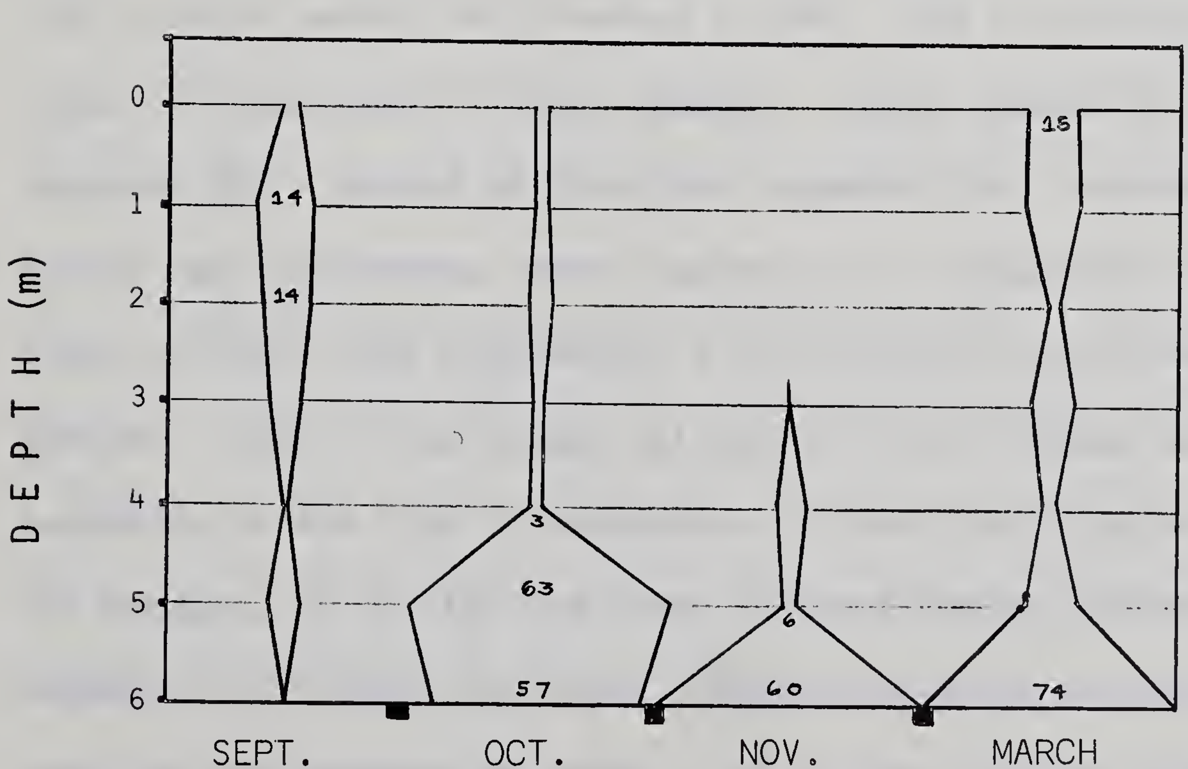


Figure 26.



C. Seasonal Cycles

For convenience in describing the seasonal cycles of the plankton algae treated quantitatively, they have been divided into several categories. Two major groups are recognized.

(1) Intermittent, which contains those algae that disappeared from the phytoplankton community for extended periods of time (two consecutive months or more).

(2) Persistent, which includes those algae that were found on every sampling date (with the exception of the February collections). The Intermittent class is divided into two groups which are separated on the basis of the duration of their algal cycles in time. Those algae that appeared in the phytoplankton community for a period of one to four weeks, during each occurrence throughout the year (often several occurrences were exhibited), were classed as (a) *Stenochronic* (Gk. *Stenos= narrow;* Gk. *chronos = time; thus stenochronic = narrow range of occurrence in time*) species. Those species of algae that appeared for a period of time that exceeded four consecutive weeks, during each occurrence, were classed as (b) *Eurychronic* (Gk. *Euros = broad or wide; thus eurychronic = wide range of occurrence in time*) species. Each of the groups (a) and (b) were further sub-divided according to the time of occurrence of their algal pulse or pulses. For example, if an alga was found to occur during the period of September to October for eight consecutive weeks and again from May to June for six consecutive weeks (that is two distinct pulses) and the September to October pulse showed a higher concentration of cells than

the latter pulse, this alga was classified as a eurychronic species with a fall maximum and a spring minimum. If an alga appeared only during the month of October for a period of three consecutive weeks, according to this classification scheme, it is called a stenochronic species with a fall maximum.

The classification of the phytoplankton from both study lakes appears below. The seasonal cycle of one alga from each group was selected and plotted to represent the periodicities of the algae within the group.

1. Intermittent

(a) Stenochronic

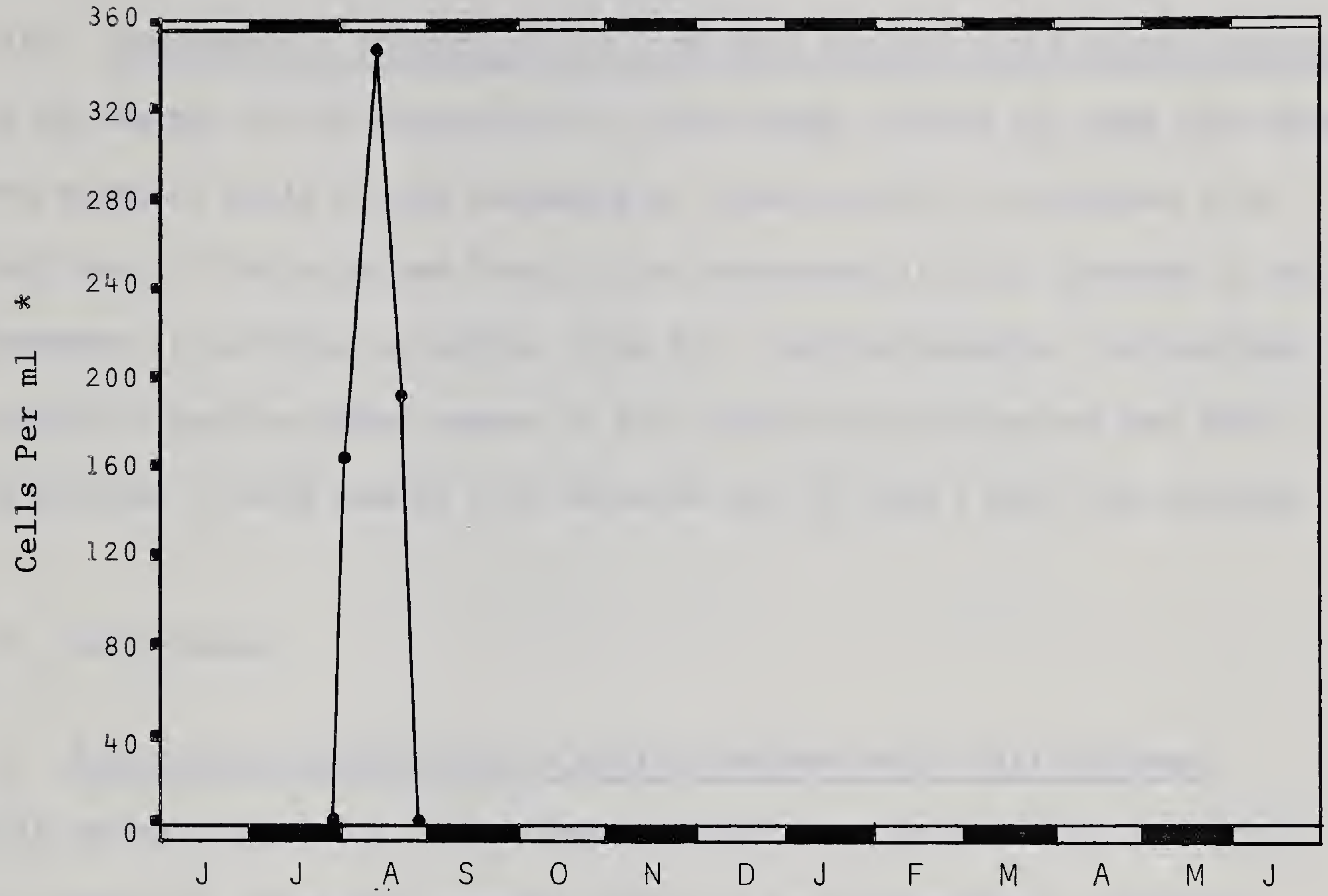
(i) Stenochronic species with a summer maximum. Figure 27, page 162, shows the periodicity of *Anabaena circinalis* at station 1 in Hastings Lake. *Anabaena macrospora* in Muir Lake showed a similar periodicity as it appeared on August 11, reached a maximum concentration of nearly 2,000 cells/ml by August 25 and then disappeared by September 8.

(ii) Stenochronic species with a spring maximum. Figure 28, page 162, shows the seasonal cycle of the green alga *Treubaria setigerum* at station 1 in Muir Lake. This alga was the only species found with this type of periodicity. Two sampling dates (May 12 and May 26) showed the presence of this species.

Figure 27. Periodicity of *Anabaena circinalis* at station 1 in Hastings Lake from June 1965 to June 1966 inclusive. Example of a stenochronic species with a summer maximum.

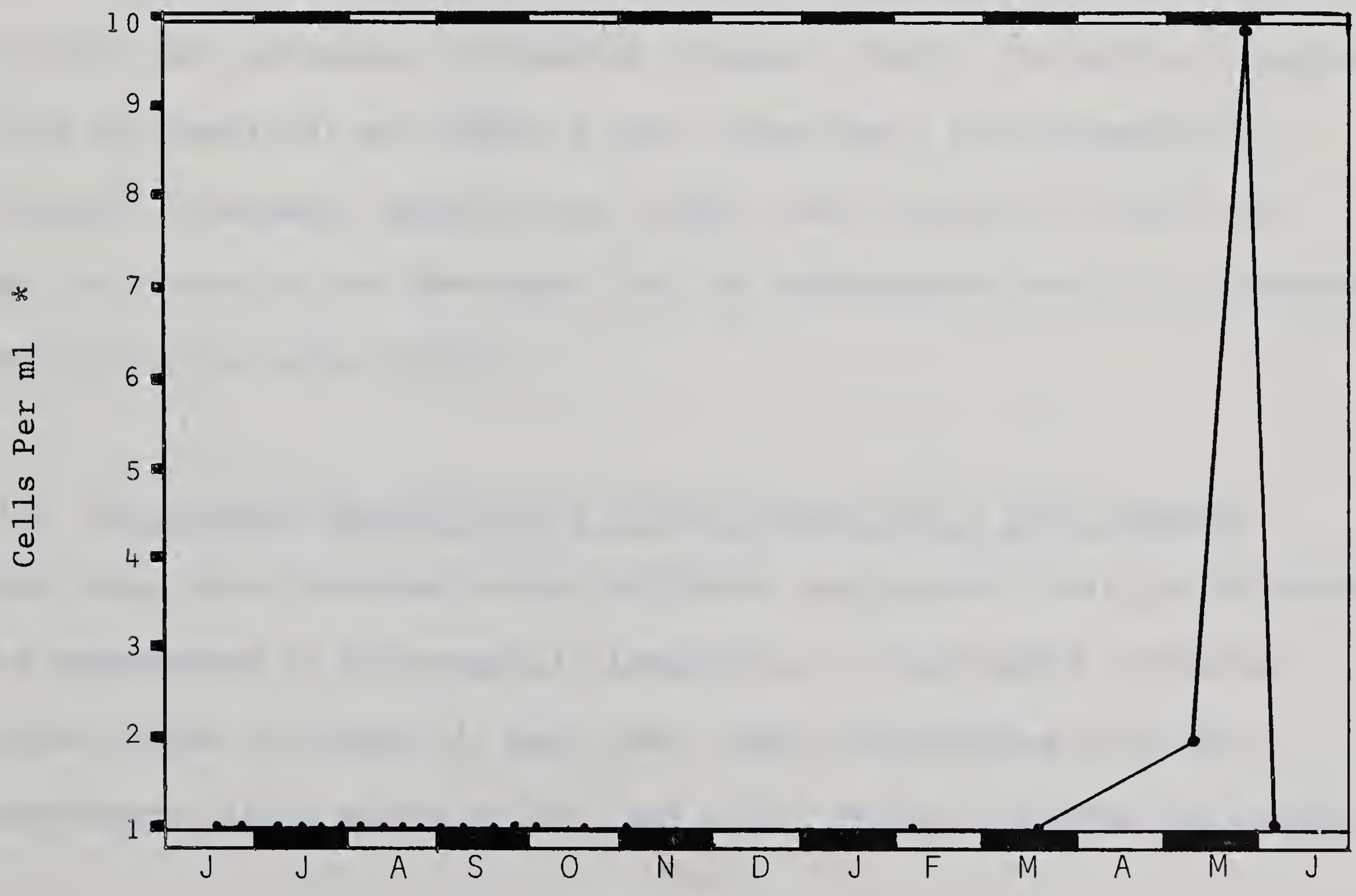
Figure 28. Periodicity of *Treubaria setigerum* at station 1 in Muir Lake from June 1965 to June 1966 inclusive. Example of a stenochronic species with a spring maximum.

Figure 27.



* For details see Appendix B_2

Figure 28.



* For details see Appendix B_1

(iii) Stenochronic species with a late fall maximum and a spring minimum. As an example of the periodicity of this group, Figure 29, page 164, shows the seasonal cycle of the Chrysophyte, *Synura uvella,* at station 1 in Muir Lake. This alga was found on two occasions in fall (October 17 and November 1) and once in spring (June 6). The Chrysophyte, *Uroglenopsis americana* was the other member of this periodicity group and was found on October 17 with nearly 1300 cells/ml and on June 6 with 100 cells/ml.

(b) Eurychronic

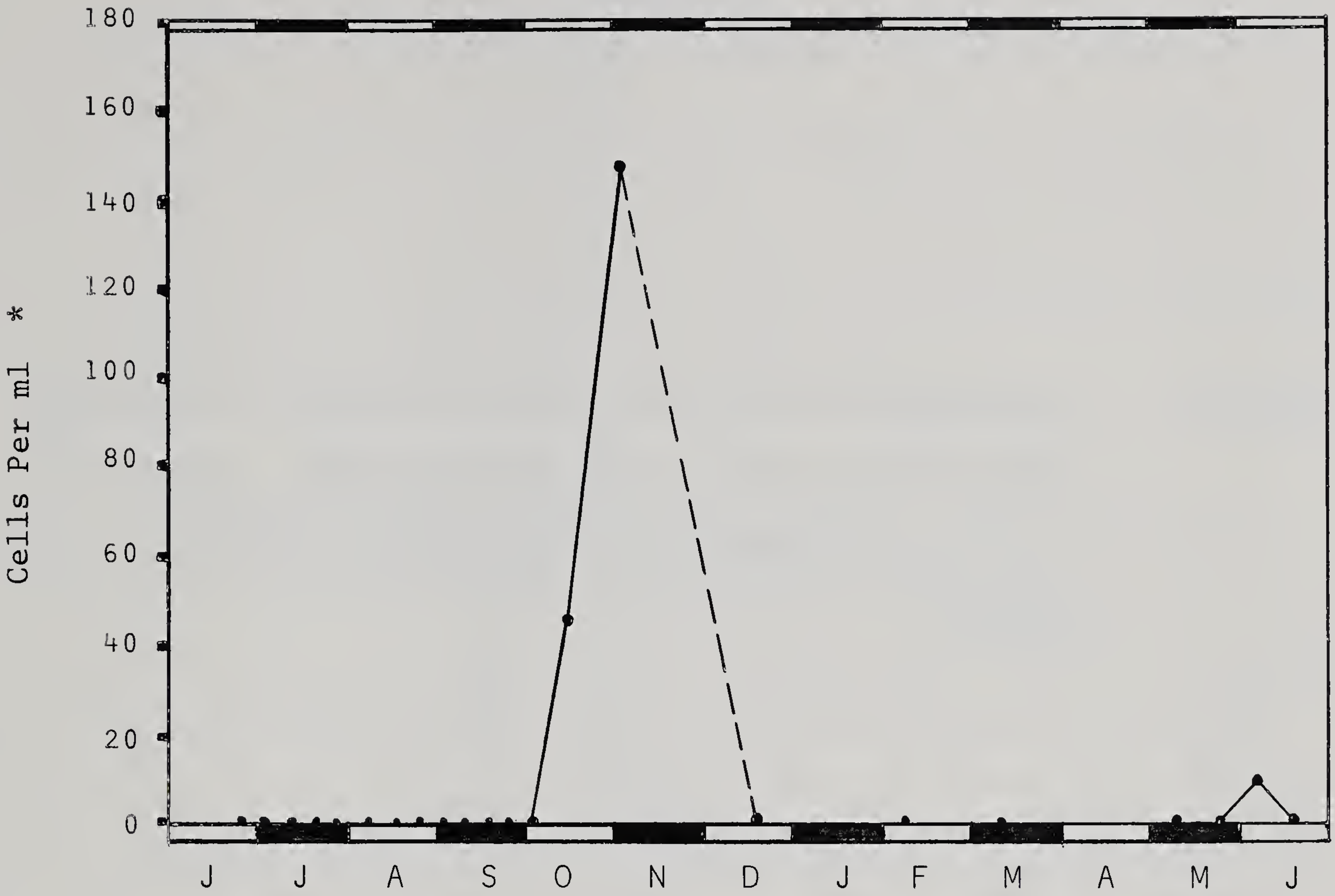
(i) Eurychronic species with a spring maximum and a fall minimum. This group contained a large number of different species (11). Figure 30, page 164, shows the seasonal cycle of the Chrysophyte, *Dinobryon sertularia,* at station 1 in Muir Lake. Other algae with a periodicity of this type included the Chlorophytes *Lagerheimia quadriseta, Staurastrum survatum* var. *paradoxum, Tetraëdron trigonum* (Muir), *Coelastrum microporum* (Muir and Hastings) and *Oocystis parva* (Hastings); the Chrysophytes *Dinobryon divergens, Synedra ulna* (Muir), and *Tabellaria fenestrata* var. *asterionelloides* (Hastings); and the Pyrrophytes *Peridinium gatunense,* and *Cryptomonas erosa* (Muir).

(ii) Eurychronic species with a spring minimum and a fall maximum. This group also contained eleven different species and their periodicities are represented by the seasonal distribution of the desmid *Closterium acutum*, shown in Figure 31, page 165. Other Chlorophytes that were eurychronic with a spring minimum and a fall maximum included *Cerasterias*

Figure 29. Periodicity of *Synura uvella* at station 1 in Muir Lake from June 1965 to June 1966 inclusive. Example of a stenochronic species with a late fall maximum and spring minimum.

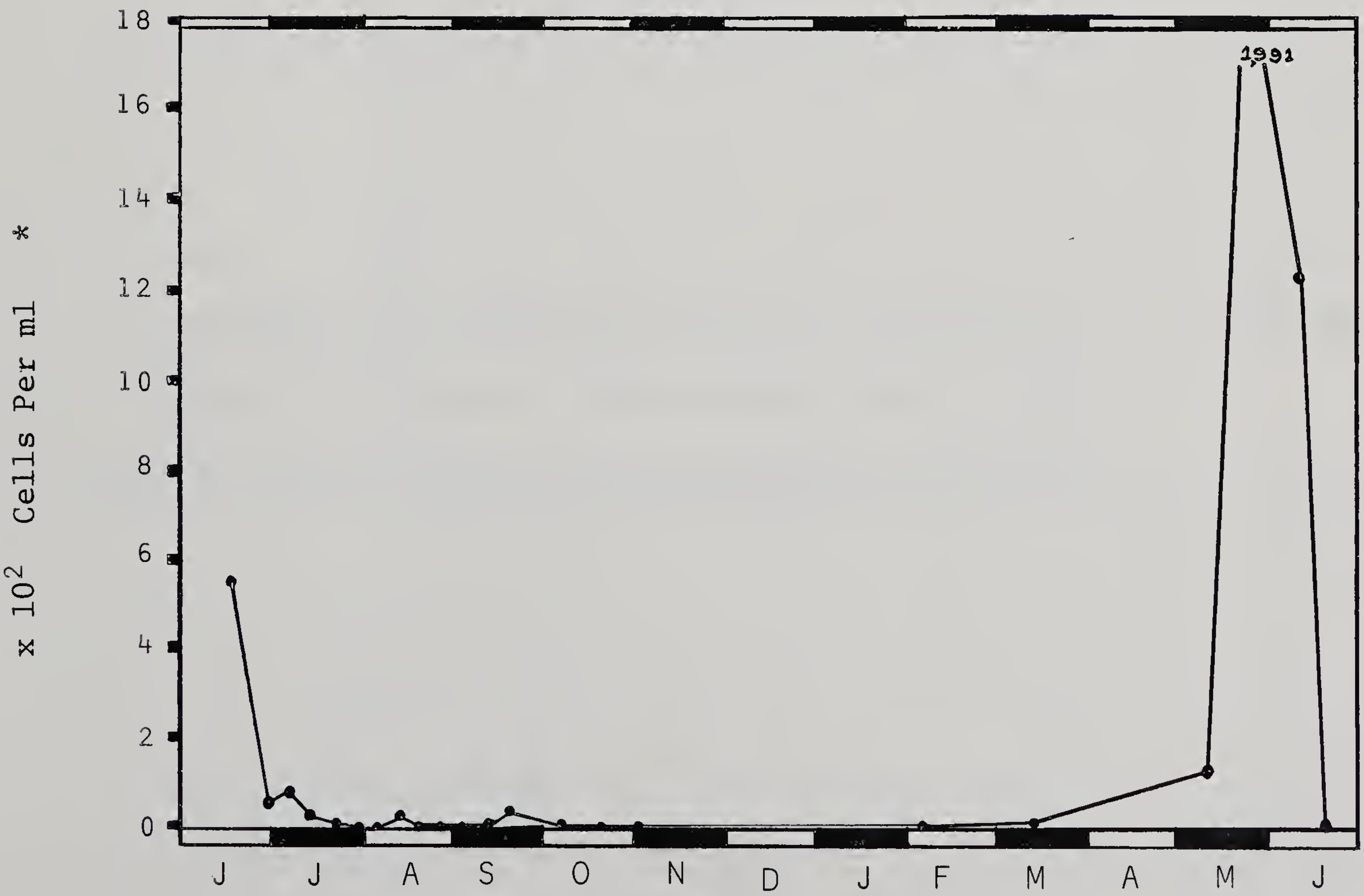
Figure 30. Periodicity of *Dinobryon sertularia* at station 1 in Muir Lake from June 1965 to June 1966 inclusive. Example of a eurychronic species with a spring maximum and a fall minimum.

Figure 29.



* For details see Appendix B_1

Figure 30.

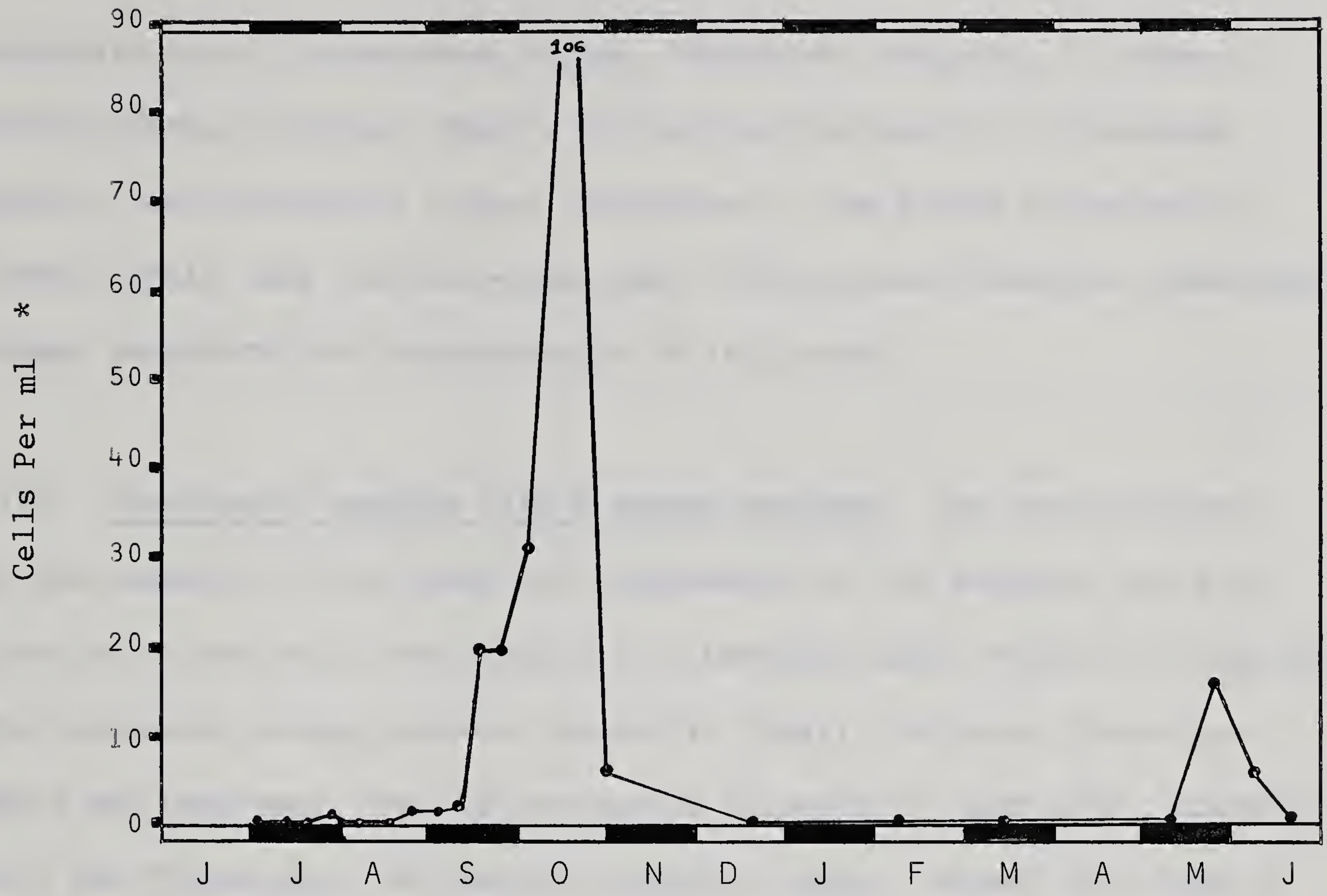


* For details see Appendix B_1

Figure 31. Periodicity of *Closterium acutum* at station 1 in Hastings Lake from June 1965 to June 1966 inclusive. Example of a eurychronic species with a spring minimum and a fall maximum.

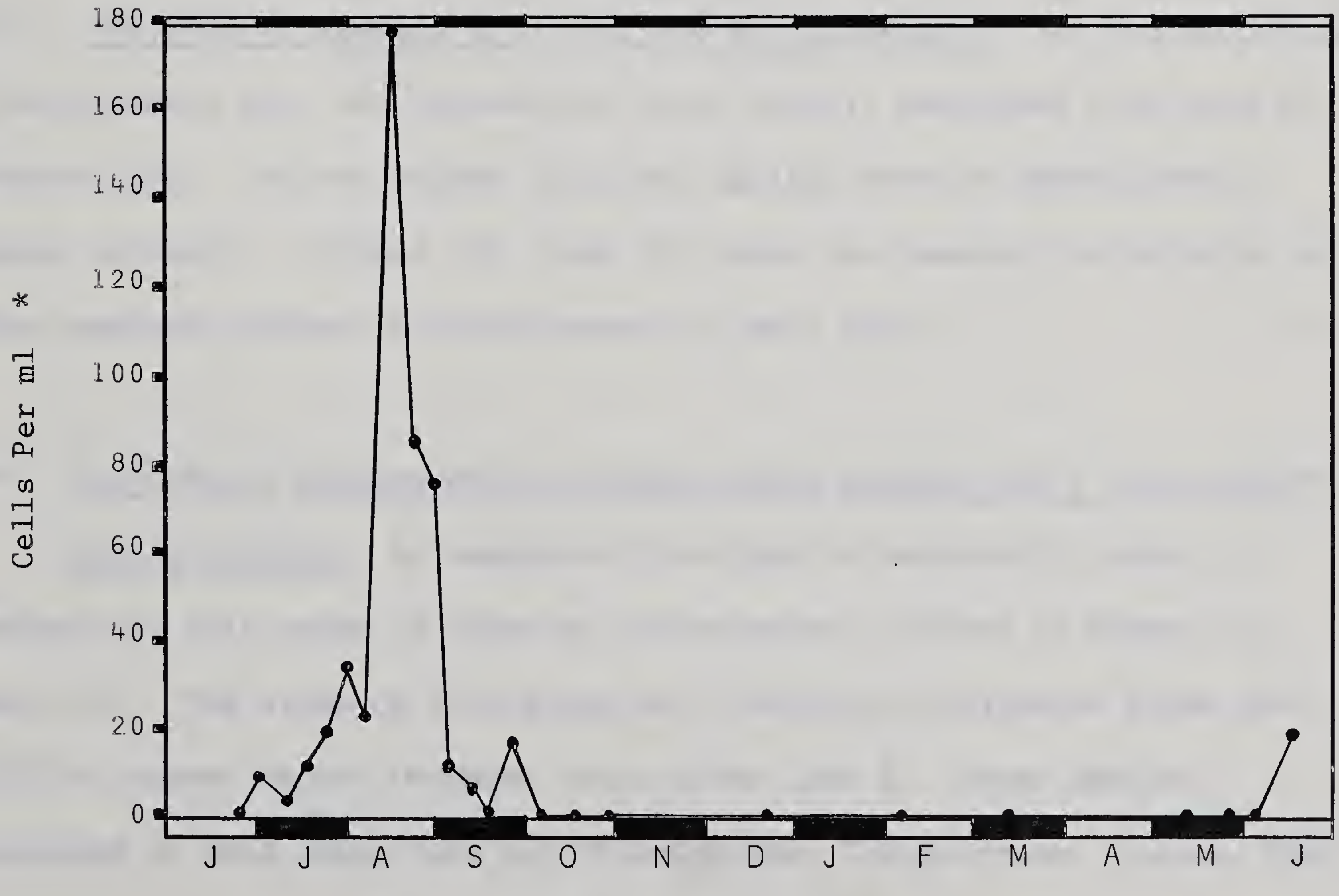
Figure 32. Periodicity of *Ceratium hirundinella* at station 2 in Hastings Lake from June 1965 to June 1966 inclusive. Example of a eurychronic species with a summer maximum.

Figure 31.

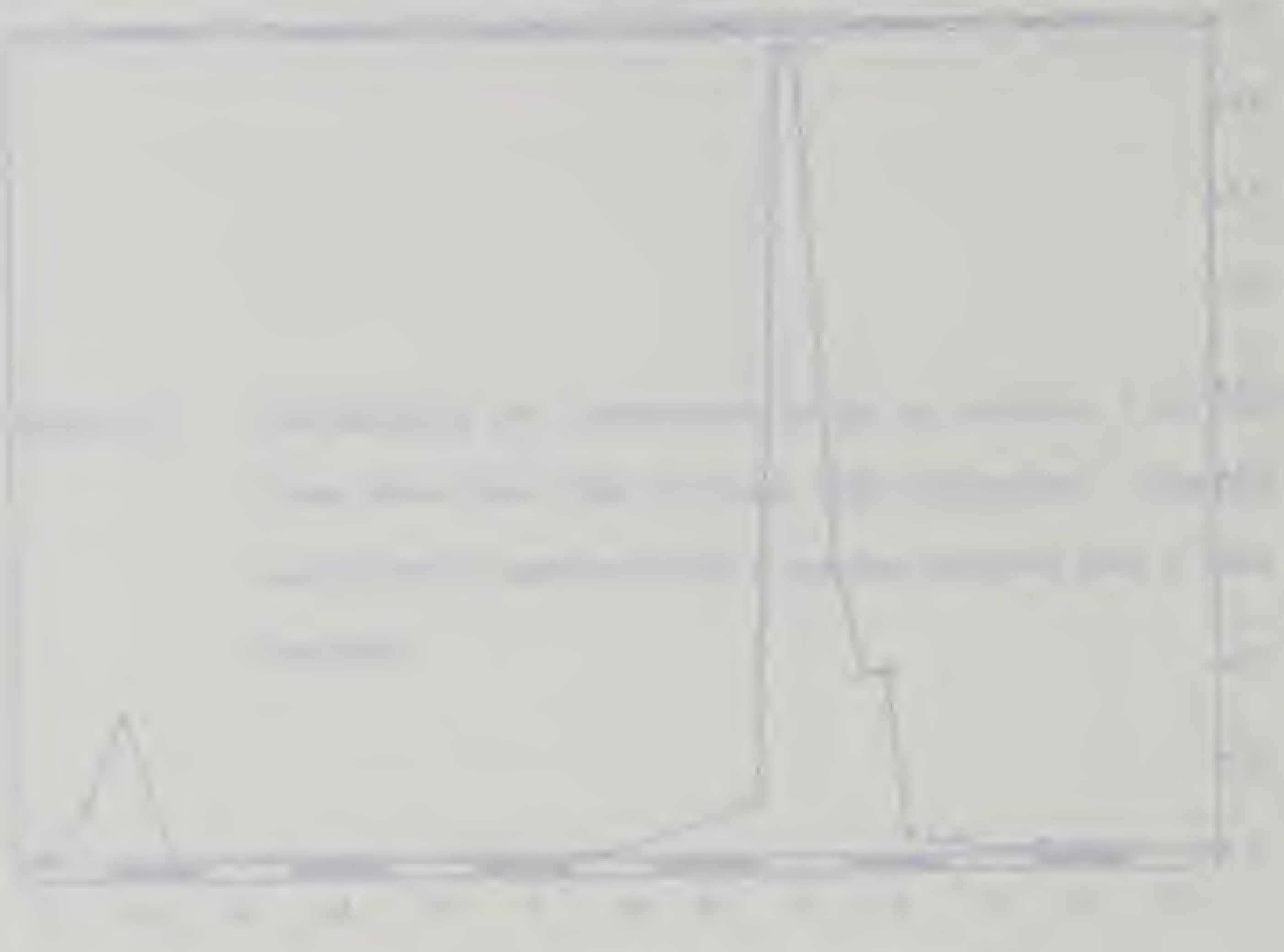


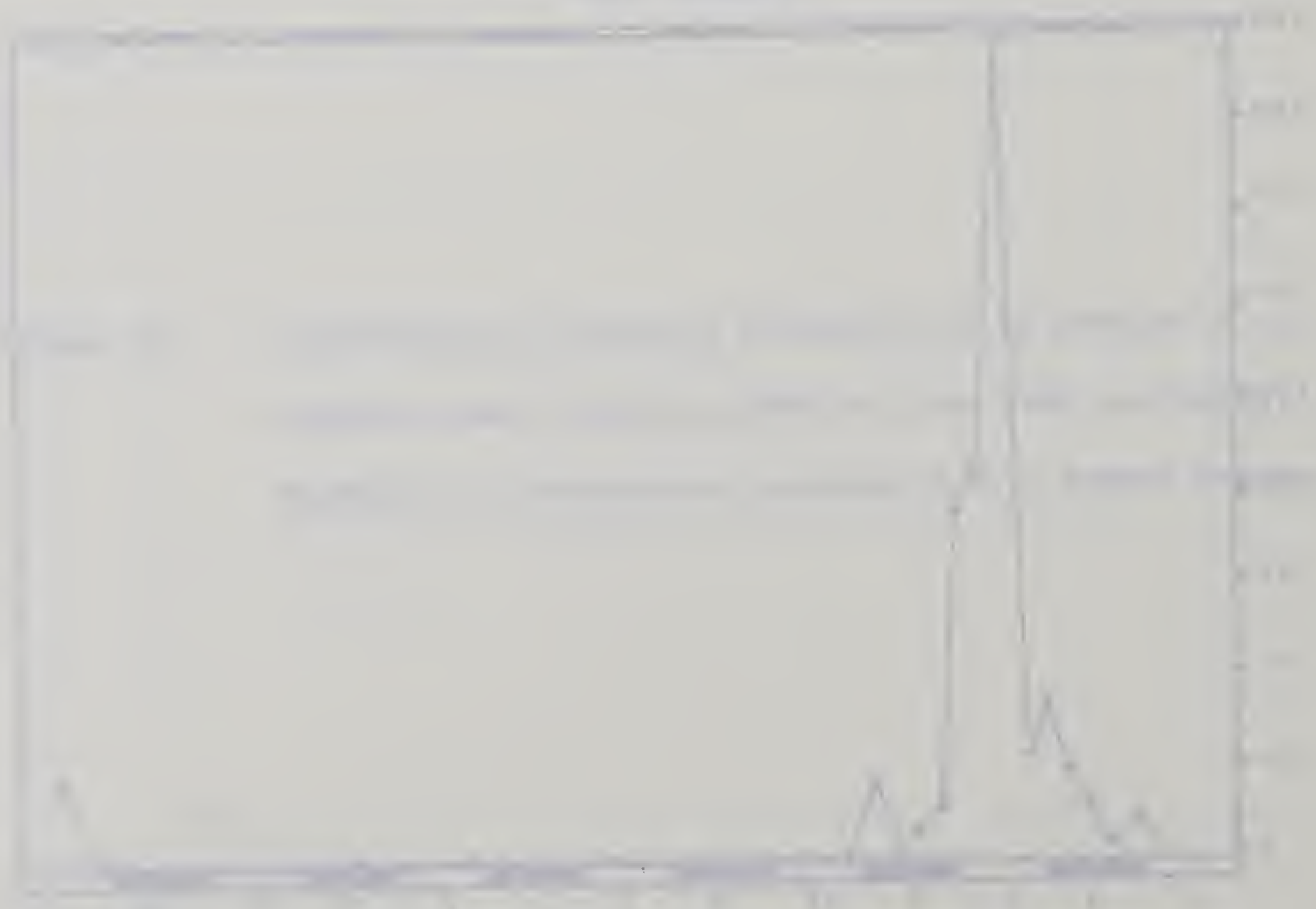
* For details see Appendix B_2

Figure 32.



* For details see Appendix B_2





staurasteroides, Scenedesmus bijuga, Pediastrum boryanum, P. tetras, Ankistrodesmus falcatus (Muir), *Actinastrum hantzschii, Selenastrum gracile,* and *Scroederia judayi* (Hastings). The diatom *Asterionella formosa* (Muir) and the blue-green alga, *Chroococcus limneticus* (Hastings), showed periodicities characteristic of this group.

(iii) Eurychronic species with a summer maximum. The periodicities of the members of this group are represented by the seasonal cycle of *Ceratium hirundinella* for station 2 in Hastings Lake (Figure 32, page 165) The blue-green algae *Anabaena circinalis* (Muir), *Anabaena flos-aquae* (Muir and Hastings), and *Coelosphaerium naegelianum* (Hastings), together with the Chrysophyte, *Mallomonas acaroides* (Muir), showed this type of seasonal periodicity.

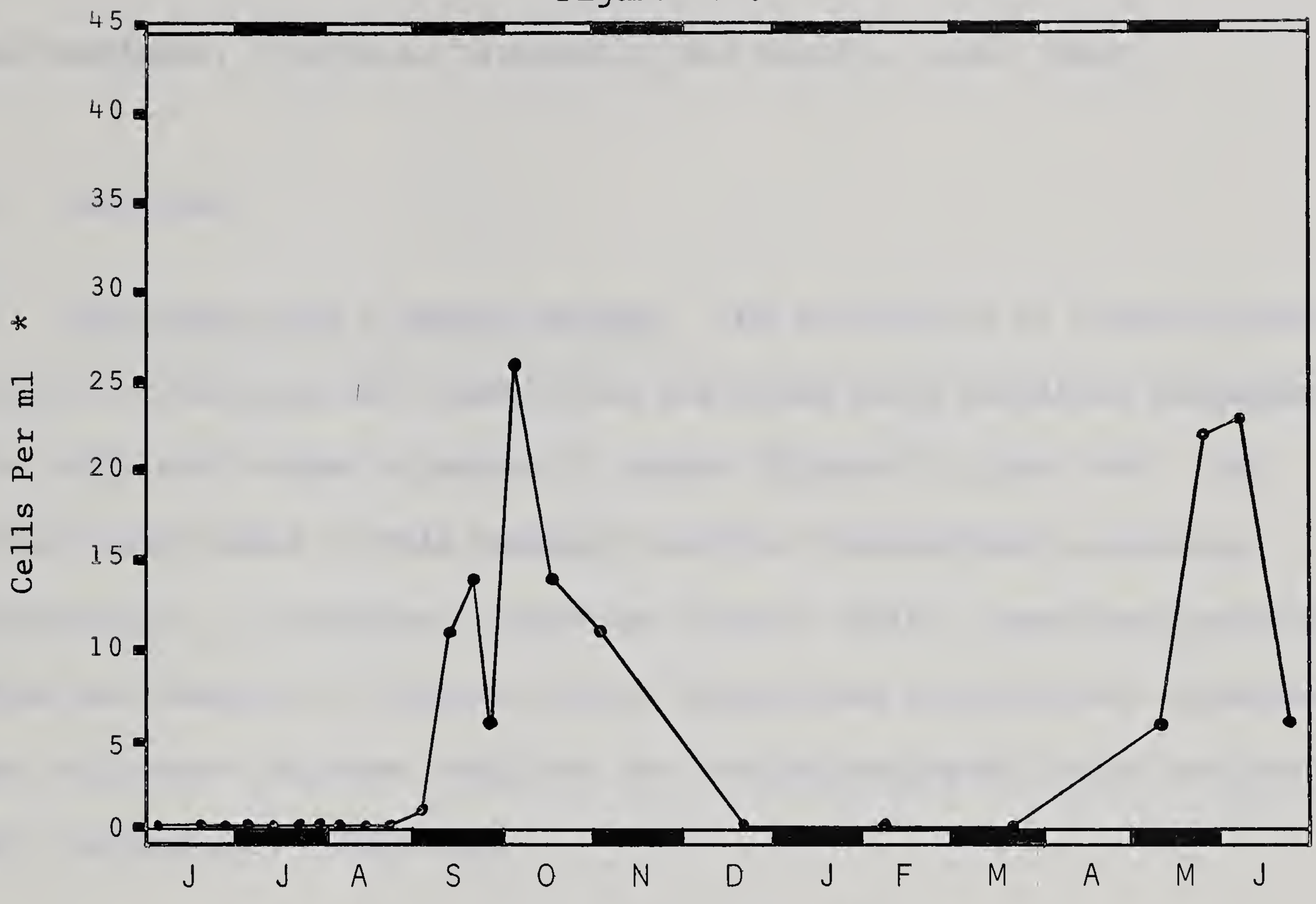
(iv) Eurychronic species with fall and spring maxima. The Euglenophytes, *Trachelomonas spp.* and *Lepocinclis acuta* (Muir), exhibited this type of periodicity. The two pulses (fall and spring) were of approximately equal intensity. Figure 33, page 167 shows the seasonal periodicity of the combined species of *Trachelomonas* in Muir Lake.

(v) Eurychronic species with an early winter minimum and a late winter-spring maximum. An example of the type of periodicity shown by members of this group is given by *Chlamydomonas globosa* in Figure 34, page 167. The algae of this group are distinctly cold water forms that did not appear before December 18 or after June 6. Those species included in this group were all Chlorophytes; *Chlamydomonas globosa* (Muir

Figure 33. Periodicity of *Trachelomonas spp.* at station 1 in Muir Lake from June 1965 to June 1966 inclusive. Example of a eurychronic species with spring and fall maxima.

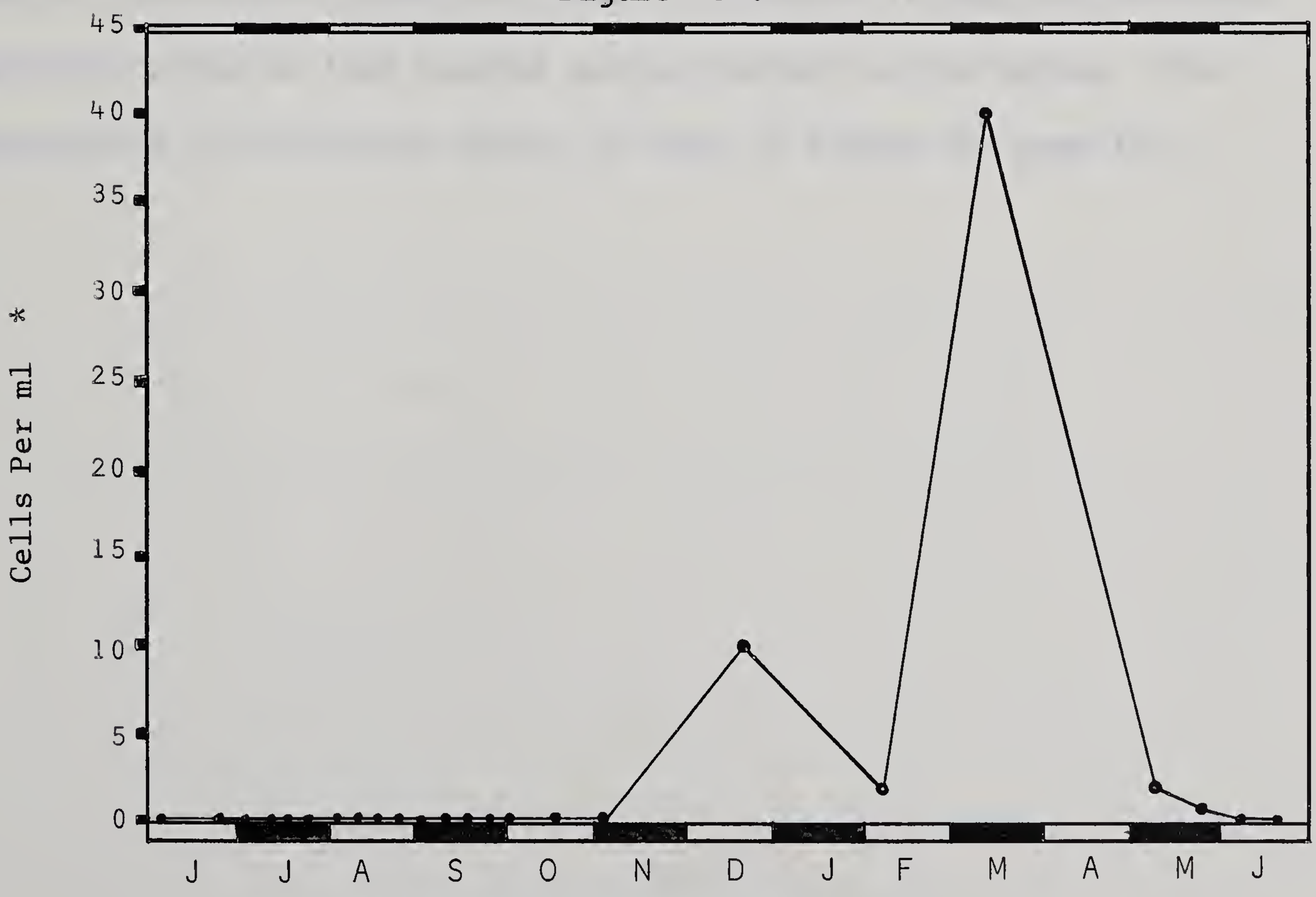
Figure 34. Periodicity of *Chlamydomonas globosa* at station 1 in Muir Lake from June 1965 to June 1966 inclusive. Example of a eurychronic species with an early winter minimum and a late winter-early spring maximum.

Figure 33.



* For details see Appendix B_1

Figure 34.



* For details see Appendix B_1

and Hastings), *Crucigenia tetrapedia*, and *Oocystis parva* (Muir).

2. Persistent

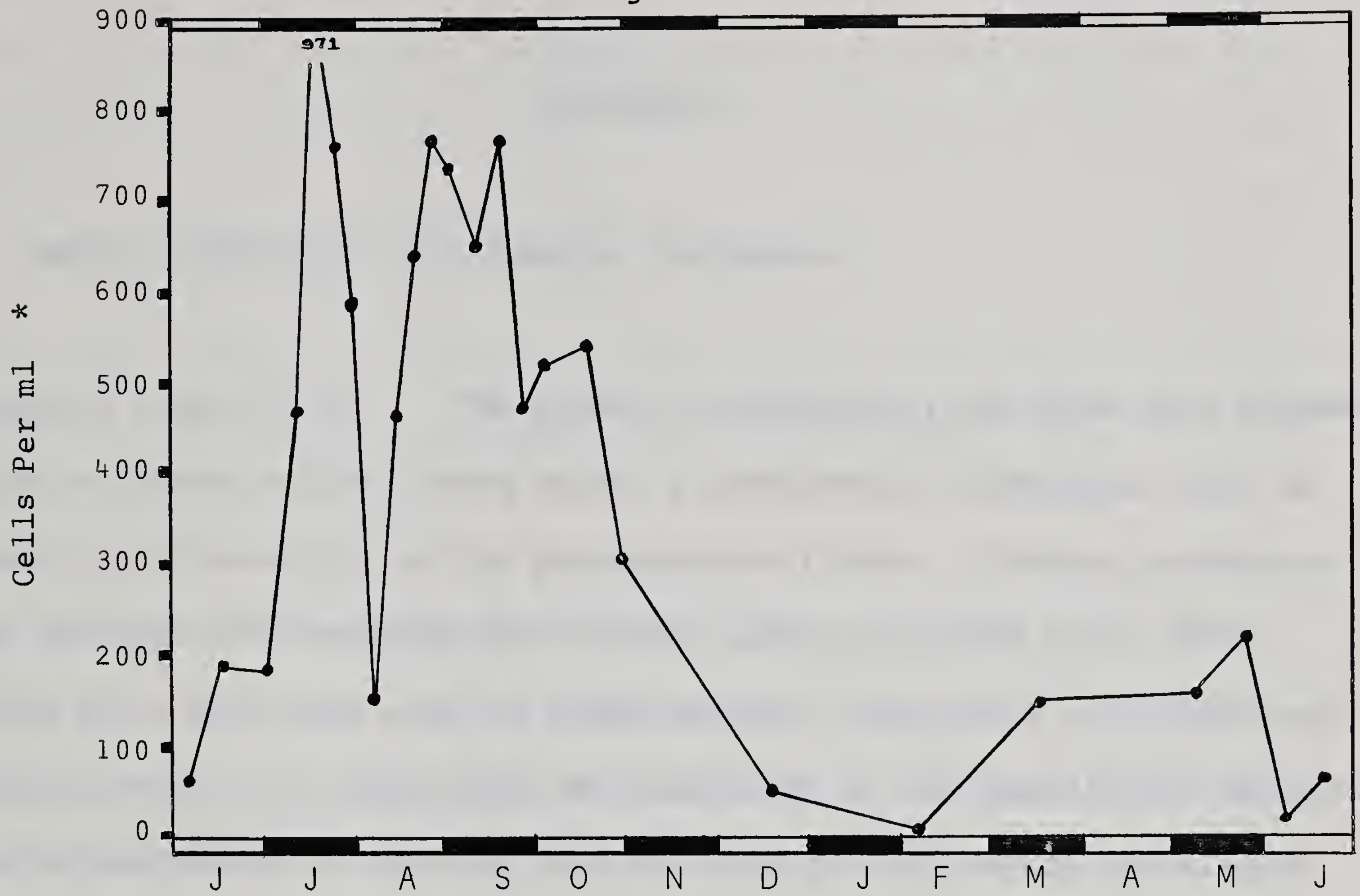
(i) Persistent with a summer maximum. The periodicity of *Stephanodiscus astraea* in Hastings Lake exemplifies the group which persisted throughout the study and reached a maximum in summer (Figure 35, page 169). The other algae placed in this category were the Chlorophytes *Scenedesmus quadricauda*, *S. dimorphus*, *Pediastrum obtusum* (Muir), *Cosmarium punctulatum* (Muir and Hastings), *Pandorina morum*, *Staurastrum curvatum* var. *paradoxum*, and *Pediastrum boryanum* (Hastings) and the Euglenophytes *Phacus nordstedtii* and *Euglena spp.* (Hastings).

(ii) Persistent with a spring maximum. The green algae *Pediastrum duplex*, *Scenedesmus quadricauda* and *S. dimorphus* in Hastings Lake were persistent species that reached maximum numbers in the spring. The periodicity of *Pediastrum duplex* is shown in Figure 36, page 169.

Figure 35. Periodicity of *Stephanodiscus astraea* at station 1 in Hastings Lake from June 1965 to June 1966 inclusive. Example of a persistent species with a summer maximum.

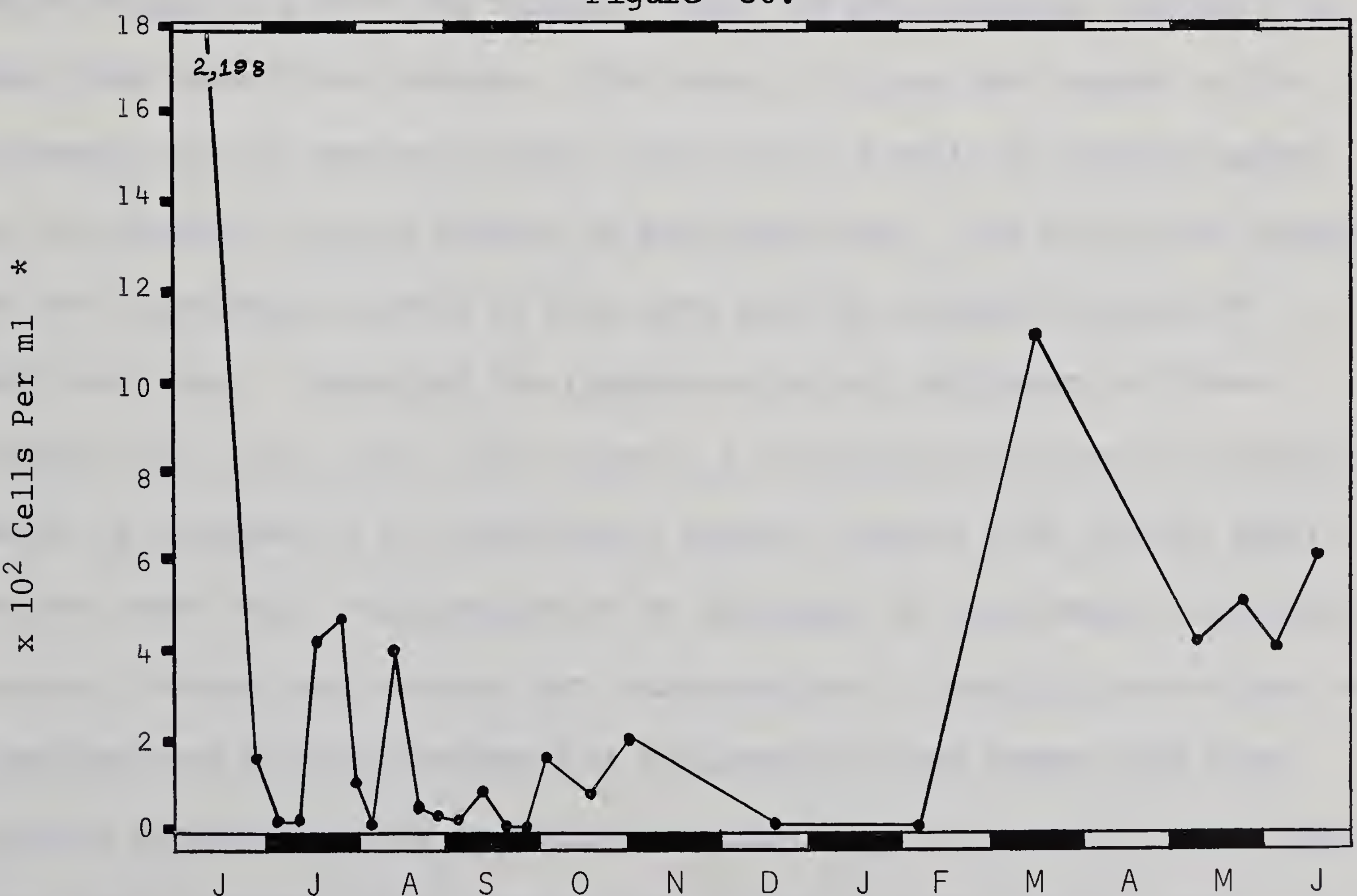
Figure 36. Periodicity of *Pediastrum duplex* at station 1 in Hastings Lake from June 1965 to June 1966 inclusive. Example of a persistent species with a spring maximum.

Figure 35.

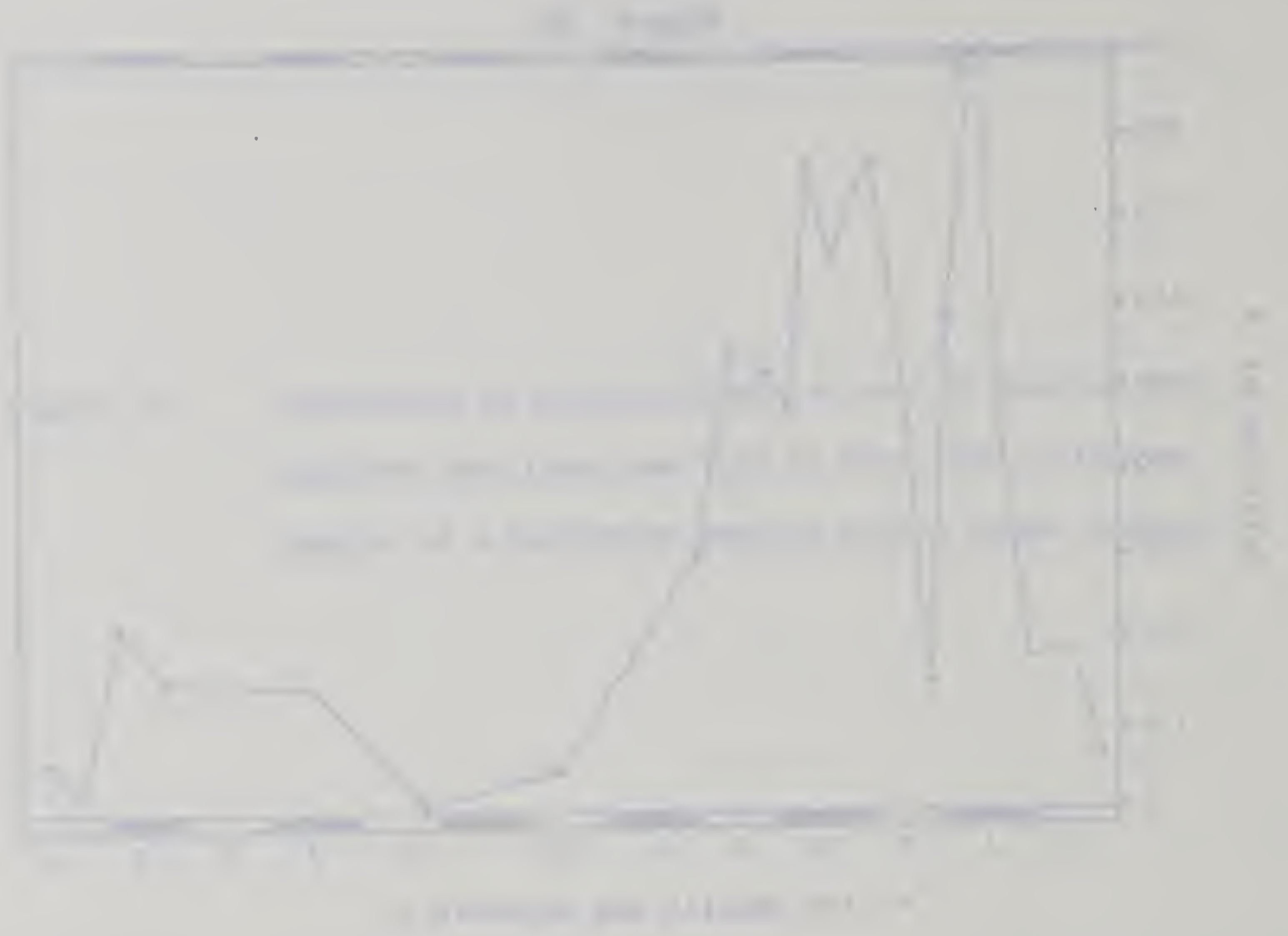


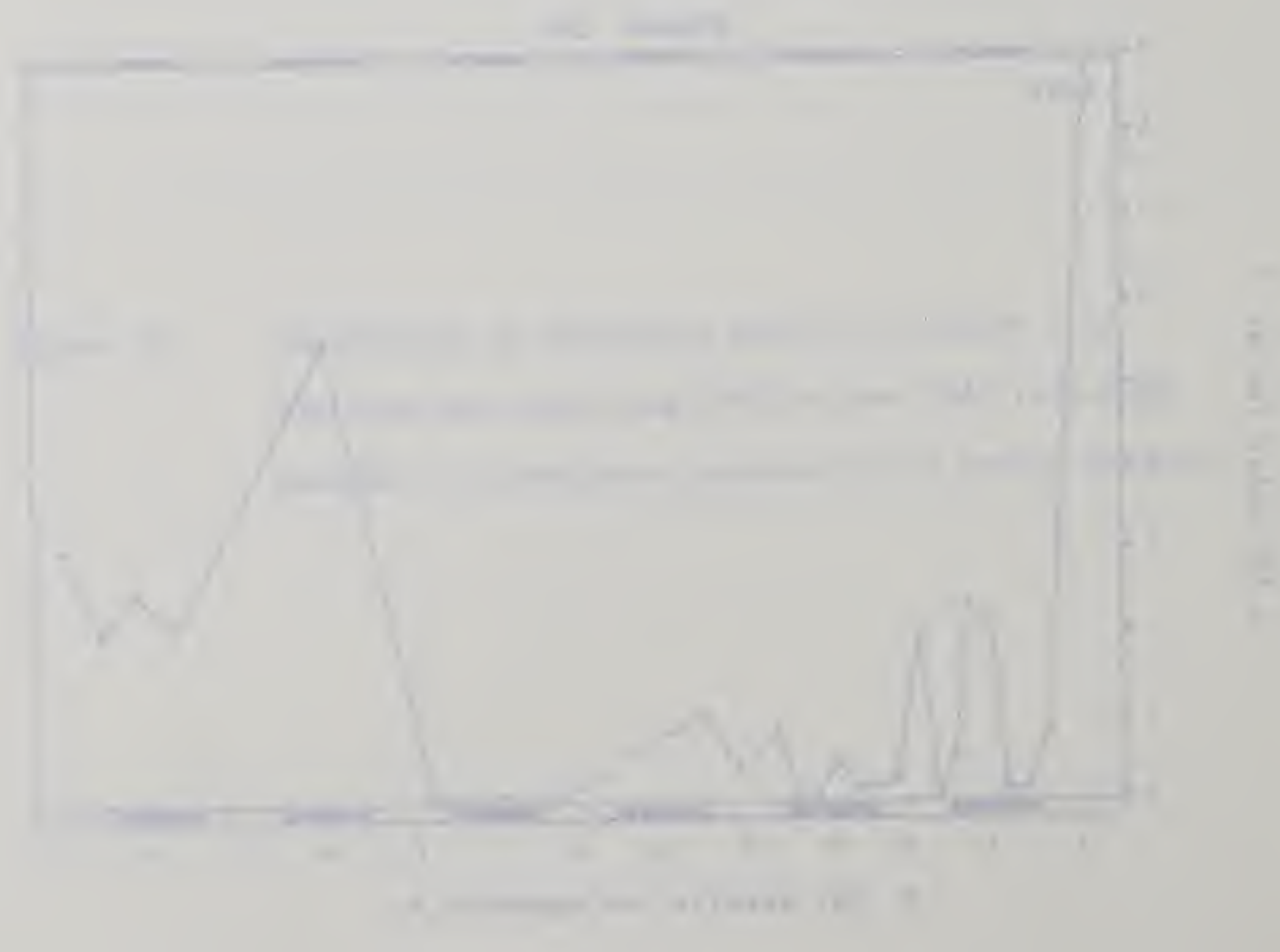
* For details see Appendix B_2

Figure 36.



* For details see Appendix B_2





DISCUSSION

A. Species Composition And Seasonal Succession

Species Composition: The present investigation has shown that between the two lakes studied, there exists a considerable difference, both in quality and quantity, of the phytoplankton floras. Plankton production at Hastings Lake exceeded that of Muir Lake by at least a 2:1 ratio. This ratio held even when the bloom species, *Microcystis aeruginosa* and *Aphanizomenon flos-aquae*, were not considered in the quantitative estimates of phytoplankton in Hastings Lake and although many minute unicellular forms were included in the phytoplankton of Muir Lake. The phytoplankton community in Hastings Lake showed great numbers of individual organisms which belong to a very few species, while the phytoplankton community in Muir Lake showed the converse. The number of algae that appear on the presence list of species in Muir Lake total 114 while 66 species appear on the presence list of species in Hastings Lake. This fact alone points to the oligotrophic nature of Muir Lake and the eutrophic nature of Hastings Lake. Concerning the presence of algal indicators of these trophic lake types, Muir Lake supports a sizeable population of *Dinobryon* which is regarded as an oligotrophic species (Rawson 1956, Willén 1962). On the other hand, the presence of an abundance of the desmids *Closterium acutum*, *Staurastrum curvatum* var. *paradoxum* and *Cosmarium punctulatum* in Hastings Lake provides evidence at variance with the common view that desmids characterize the phytoplankton community of an oligotrophic lake. The widely accepted algal groups used to indicate the trophic level of a

lake appear to be too all-inclusive, as the exceptions indicate. For example, the desmids listed above were fairly abundant in Hastings Lake, which is eutrophic, and the desmids *Staurastrum curvatum* var. *paradoxum* and *Cosmarium punctulatum*, although present in Muir Lake, appeared in very small numbers. Perhaps individual species of phytoplankton could be used as indicators of trophic levels of lakes much more effectively than entire algal groups.

Rawson (1956) points out that it is very unsafe to assume that eutrophic plankton is poor in numbers of species. It may only appear so because the rarely occurring species are very difficult to find among the very abundant forms. I am in complete agreement with Rawson's view and feel that an algal investigator, unconsciously, devotes more time to the microscopic examination of a water sample from an oligotrophic lake with a sparse distribution of algae than to a sample in which many organisms are present.

Many species of plankton algae were found in one lake and not in the other. For example, of the more important forms, *Tribonema*, *Closterium acutum*, *Tabellaria* and *Stephanodiscus* were found only in Hastings Lake, while *Dinobryon*, *Uroglenopsis*, several *Oscillatoria* species, and *Oedogonium* were present only in Muir Lake. However, an examination of the presence lists shows that a great many species were common in both lakes although they differed markedly in their abundance, for example, *Pandorina*, *Pediastrum*, *Coelastrum*, *Actinastrum* and *Staurastrum*. The majority of phytoplankton common to both study lakes were considerably more abundant in Hastings Lake. The four species, *Lagerheimia quadriseta*,

Ankistrodesmus falcatus, Tetraëdron limneticum and *Mallomonas acaroides* were exceptions to this situation.

A possible explanation for the small quantity of phytoplankton in Muir Lake may be found in the effects of macrophytes and epipelic algae. Several physical factors are conducive to the development of an extensive aquatic macrophytic flora in Muir Lake. One of these factors is light penetration. Light is able to penetrate the water to the bottom because of the absence of suspended silt and clay. Another factor is that of wind. As the lake is well protected from winds and little particulate matter remains in suspension, there is increased sunlight penetration. The extensive growth of aquatic macrophytes and the mat of *Oscillatoria* on the bottom sediments in Muir Lake are apt to tie up a large portion of the available nutrients and thereby leave an insufficient supply to support a well-stocked and healthy phytoplankton community. Hasler and Jones (1949) demonstrated that algae and rotifers were inhibited by the presence of aquatic macrophytes. Jørgensen (1957), on the basis of field observations and laboratory experimentation, found that epiphytic diatoms were directly antagonistic to planktonic forms. Suppression of the growth of phytoplankton by aquatic macrophytes and epiphytic algae seems to be a likely occurrence in Muir Lake.

The water chemistry of the two lakes differs, probably as a result of the difference in the size of their respective drainage areas. Hastings Lake has a considerably larger drainage area and contained a greater concentration of the nutrients phosphorus and nitrogen and a higher total dissolved substances (T.D.S.) content than did Muir Lake.

The organic matter content of Hastings Lake is much higher than that of Muir Lake, and possibly because of this factor, supports an abundant blue-green algal population which reaches bloom proportions in late summer. No such algal bloom was evident in Muir Lake during this study and reports of investigations conducted on Muir Lake by Carefoot (1959) include a similar observation.

According to the definitions of and distinctions between lakes and ponds (Round 1965), Muir Lake is a pond while Hasting Lake is a true lake. Round states that although "it is almost impossible to make a distinction between ponds and lakes, yet the flora is frequently quite different; useful criteria in defining ponds (irrespective of local naming) are, the absence of wind induced wave moulding of the shoreline, the relatively shallow depth, the small volume leading to rapid changes in composition of the water and the rapid fluctuations of temperature, carbon-dioxide and pH." This same author points out that well developed epiphytic and epipelic algal communities are also characteristic of ponds and that the phytoplankton is often augmented from the other algal communities. There is considerable difficulty, however, in segregating the euplankton algae from epipelic or awfwuchs species that have been carried into the open water. Many authors (e.g. Williams 1962) use the terms euplankton and benthic algae, but fail to define these terms or to make clear their usage. Throughout this investigation, those algae which were relatively more abundant in the epiphytic or awfwuchs community were considered as epiphytic species, while those species which were most commonly found in the open water community were considered as euplankton species.

There are definite limitations to the data obtained from an ecological study of one year duration. The year chosen for study may show a set of environmental conditions that are very different from those of the long-time average. Consequently, those phytoplankton species which are usually abundant and play a leading role in the community dynamics, may be absent or play a leading role in the community. Bethge (Round 1965) studied the phytoplankton of a small pond in Berlin from 1929 to 1944 and presented comprehensive data on seasonal and year to year occurrences of these algae. He gives evidence for the occurrence of certain algal species every year and of certain species which were absent some years and present in others. Thus one should have observations from several years to arrive at any generalizations about phytoplankton community dynamics.

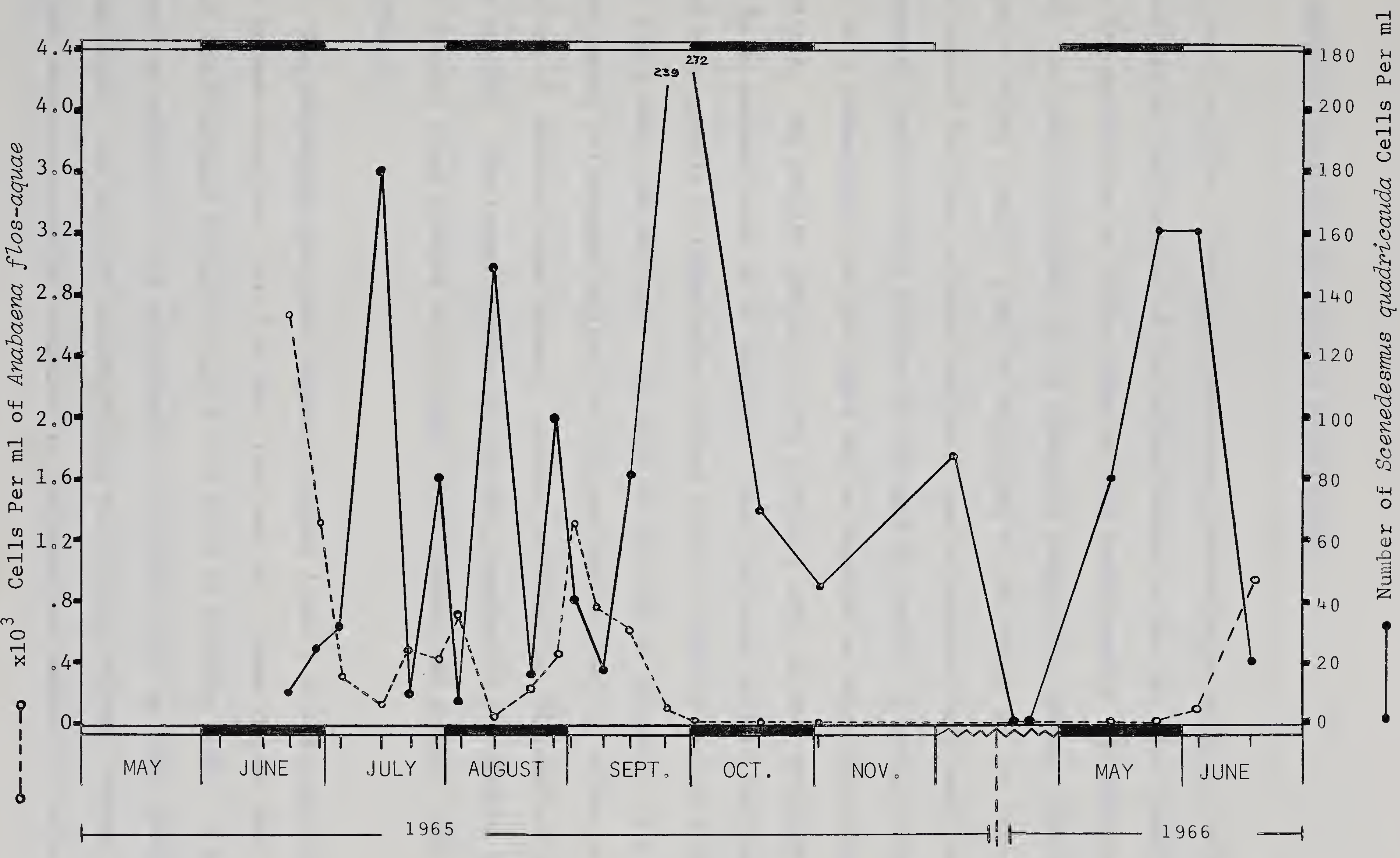
Seasonal Succession: The literature dealing with the phenomenon of rapid fluctuations of algal populations and the rapid replacement of dominants in succession is replete with attempts to relate these occurrences to the chemical and physical factors of the environment. To date no clear-cut relationships are known to exist between these rapid fluctuations and the levels of the various nutrients or light and temperature conditions. However, a wealth of evidence has been produced by numerous workers to indicate that many algal species are capable of producing physiologically active substances which act as either growth stimulators, toxins or growth inhibitors (Hartman 1960).

From the results of the seasonal studies of the phytoplankton in both lakes, the outstanding observation was that the blue-green alga

Anabaena flos-aquae appeared to exert an inhibitory or antagonistic effect on the growth of several green algae such as *Scenedesmus* and *Pediastrum*. With few exceptions, whenever the population of *Anabaena flos-aquae* increased from the numbers found on the previous sampling date, the population of the green alga *Scenedesmus quadricauda* decreased (Figure 37, page 176). All species designated as anti-blue-green showed a reaction to increased *Anabaena flos-aquae* populations similar to the reaction exhibited by *Scenedesmus quadricauda*. According to Hammer (1964) and Hartman (1960), substances produced by *Anabaena flos-aquae* are toxic and inhibitory to some algae. Present studies provide further evidence that such substances are a factor in seasonal succession of phytoplankton.

Almost as striking was the apparent effect of *Anabaena flos-aquae* on the dinoflagellate *Ceratium hirundinella* in Hastings Lake. The seasonal cycles of these two species were almost identical. In this case, these extracellular metabolic substances may cause the inhibition or removal of certain green algae which suppress the growth and development of *Ceratium hirundinella*, or it is possible that these organic compounds stimulate the growth of this alga.

Figure 37. Variations in the number of cells of *Anabaena flos-aquae* and *Scenedesmus quadricauda* per ml at station 1 in Muir Lake.


x10^3 Cells Per ml of Anabaena flos-aquae
Number of Scenedesmus quadricauda Cells Per ml
4.4
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
.8
.4
0
180
200
180
160
140
120
100
80
60
40
20
0
239
272
MAY
JUNE
JULY
AUGUST
SEPT.
OCT.
NOV.
MAY
JUNE
1965
1966

B. Regional Variation And Vertical Distribution

Regional Variation: The significant station-to-station variation in the quantitative distribution of the phytoplankton in the two lakes opens the way for speculation as to the cause of this heterogeneity. In Hastings Lake, the great difference in the community composition between station 2 and stations 1 and/or 3 may be attributed to the nature of the lake basin. The area of the lake in which station 2 lies is comparatively small and separated from the large portion of the lake by narrows of shallow water, and as a consequence, the two areas may be regarded as separate ecological habitats. The smaller portion of the station 2 area is much shallower (3.5m as compared with 9m at station 1) than the large portion and reacts much more quickly to temperature changes since its smaller volume allows for rapid heat loss and gain. The area of the lake at station 2 is a much more severe and extreme habitat and this may have a limiting effect on the species of plankton algae present, as well as affecting colonization by new species. The larger portion of the lake, because of its greater depth, may support algal species which prefer deeper waters and reduced light intensity.

The horizontal variation between stations 1 and 3 in Hastings Lake and between stations 1 and 2 in Muir Lake was of a lesser degree than that found between stations 1 and 2 or 3 and 2 in Hastings Lake. In Muir Lake, the majority of the environmental conditions such as light penetration, temperature, and nutrient concentrations were fairly uniform, however, slight station-to-station variation in phytoplankton numbers did occur.

In general, the horizontal variation of the phytoplankton distribution in both lakes may be due to the effects of wind and water currents. Considerable 'piling-up' of blue-green algae occurred as a result of wind action and water currents. With the introduction of an abundance of one species (blue-green or any other) there is an upset in the entire community structure as competition for nutrients intensifies and the concentration of extracellular metabolic substances increases markedly. Moreover, the removal of selected species from a given area in the phytoplankton community by wind is likely to result in the maximum development of a subordinate species which had been suppressed previously at that site.

Vertical Distribution: Considerable wind mixing of the water of both lakes prevented vertical stratification of the phytoplankton for extended periods of time. Muir Lake showed a greater vertical stratification of its phytoplankton than did Hastings Lake. Three types of vertical distributions were recognized. Firstly, a number of phytoplankton species migrated rapidly to the surface following wind mixing of the water and the consequent uniform dispersion of the phytoplankton. Only motile forms such as *Ceratium hirundinella* and certain Cyanophytes, e.g. *Anabaena flos-aquae*, that form pseudovacuoles within their cells, were able to migrate in this manner.

Secondly, a large number of species were found dispersed fairly uniformly throughout the water column. *Stephanodiscus astraea* in Hastings Lake exemplifies this group which contains species with a very slow sinking rate (Lund 1950) but which would likely settle out if suspension by wind action did not occur.

Thirdly, several species inhabited the lower waters and appeared near the surface only subsequent to thorough and complete circulation of the water, such as that resulting from summer storms or the vernal and autumnal turnovers. The Euglenophyta dominated this group of bottom dwelling forms which included several species of Chrysophyceae such as *Mallomonas acaroides* (Muir Lake). Several factors may be responsible for the occurrence of these bottom dwelling forms. Among these may be listed: reduced light exposure, lower oxygen requirements, lower temperature and slightly higher available nutrient concentrations.

C. Seasonal Cycles

Transeau (1916) classified the algae, in Illinois waters, according to their seasonal occurrence. He divided the algae into winter annuals, spring annuals, summer annuals, autumn annuals, perennials and ephemerals on the basis of the time of their germination, vegetative development, sexual reproduction and dormancy. This scheme could not be applied to the algae of the two lakes studied during this investigation since only a few sexual reproductive and dormant stages of the algae were found. A few isolated filaments of *Spirogyra* (Zygnematales) were found to conjugate in autumn and cysts of *Ceratium hirundinella* were the only recognizable dormant stages found in appreciable numbers in the lakes. This scarcity of algae in the sexually reproductive state was also noted by Prescott (1963) in Arctic lakes. Many algae appear well able to endure in the vegetative condition the vicissitudes of north temperate and Arctic waters.

A great deal of confusion concerning the word pulse has arisen in the literature dealing with algal periodicities. This word has been used repeatedly, yet rarely defined. Consequently, the results of two investigators can seldom be compared. It appears that the problem arises when workers attempt to select subjectively, those species of phytoplankton which are quantitatively significant. A worker equipped with superior optics will regard even the "μ-algae" (Rodhe 1955) as quantitatively significant. We must endeavor to discover techniques which will reduce the large amount of subjectivity that enters into estimates of algal numbers or volumes, if the results of studies on algal cycles are

to become meaningful.

Algal periodicities are influenced by "factors of control" and "factors of supply (limiting factors)" (McCombie 1953). Light quality, duration of illumination and nutrient concentrations are thought to be common limiting factors, while temperature and pH are likely factors of control (McCombie). Water temperature sets the rate of metabolism in a lake and perhaps limits the occurrence of certain species of algae with narrow ranges of temperature tolerance. Prescott (1963) reported that both growth and reproduction may be carried out by algae when the water temperature is only 0.56 °C. In his study of Arctic lakes, he found that in one lake, the highest count of phytoplankton occurred at a time when the lake was scarcely above freezing and only a portion of the lake was open. In this count were included such species as *Closteriopsis longiseta*, *Uroglenopsis americana*, *Cosmarium botrytis* and *Schroederia setigera*, in all, over 2,000,000 organisms per liter. Rodhe (1955) in his studies on sub-arctic lakes reports that nannoplankton (mostly Chlorophyta) existed beneath the ice cover during the winter months in concentrations of nearly 10,000,000 cells per liter. In both lakes investigated during the present study, active growth and development of several species of algae (e.g. *Chlamydomonas globosa*) took place in waters of less than 0.5 °C.

The intensity of sunlight and the duration of illumination, as a result of increased insolation and decreased snow cover, were likely responsible for the considerable growth of many species of algae in March. It is suggested that these factors, together with the absence of competitive species, were largely responsible for the seasonal cycle of *Chlamydomonas globosa*.

The limiting effect of nutrients on the cycles of certain plankton algae has been discussed in aquatic biology for many years. A negative correlation between silica concentrations and diatom periodicity has been made repeatedly (Pearsall 1932, Hutchinson 1944, Rodhe 1948, Lund 1950). Figure 38, page 183, provides evidence in support of this negative correlation between silica and the population of *Asterionella formosa* in Muir Lake. The correlation is not striking because of the low numbers of *Asterionella formosa* in the lake, even during the population maximum. This diatom was also found to increase slightly with a slight increase in the level of nitrate-nitrogen. Several other correlations were made between the seasonal occurrence of algal species and the nitrate-nitrogen level in both study lakes. In Muir Lake, a sharp drop in *Anabaena flos-aquae* was correlated with a rise in the nitrate concentration, which suggests that decomposition and autolysis of this blue-green alga releases available nitrogen. Accompanying this increase of nitrate were increases in the cell numbers of *Peridinium gatunense*, *Pediastrum*, *Scenedesmus* and *Dinobryon divergens*. In Hastings Lake, slight increases in nitrates were correlated with increases in the numbers of the persistent diatom *Stephanodiscus astraea*.

The seasonal cycle of the Chrysophyte *Dinobryon* has been the object of intensive investigation on this continent and elsewhere. Both Pearsall (1930) and Hutchinson (1944) found that *Dinobryon* occurred in phosphate and nitrate rich waters. Rodhe, on the other hand, found that high phosphate concentrations were destructive to *Dinobryon*, as the cells would evacuate their envelopes (loricas) in high phosphate concentrations (5-10 μ gm P per liter). Figure 39, page 184 shows that a relationship exists between the cell numbers of *Dinobryon divergens* and the level of ortho-

Figure 38. Variations in the number of cells of *Asterionella formosa* and the concentration of silica in Muir Lake for the period of study.

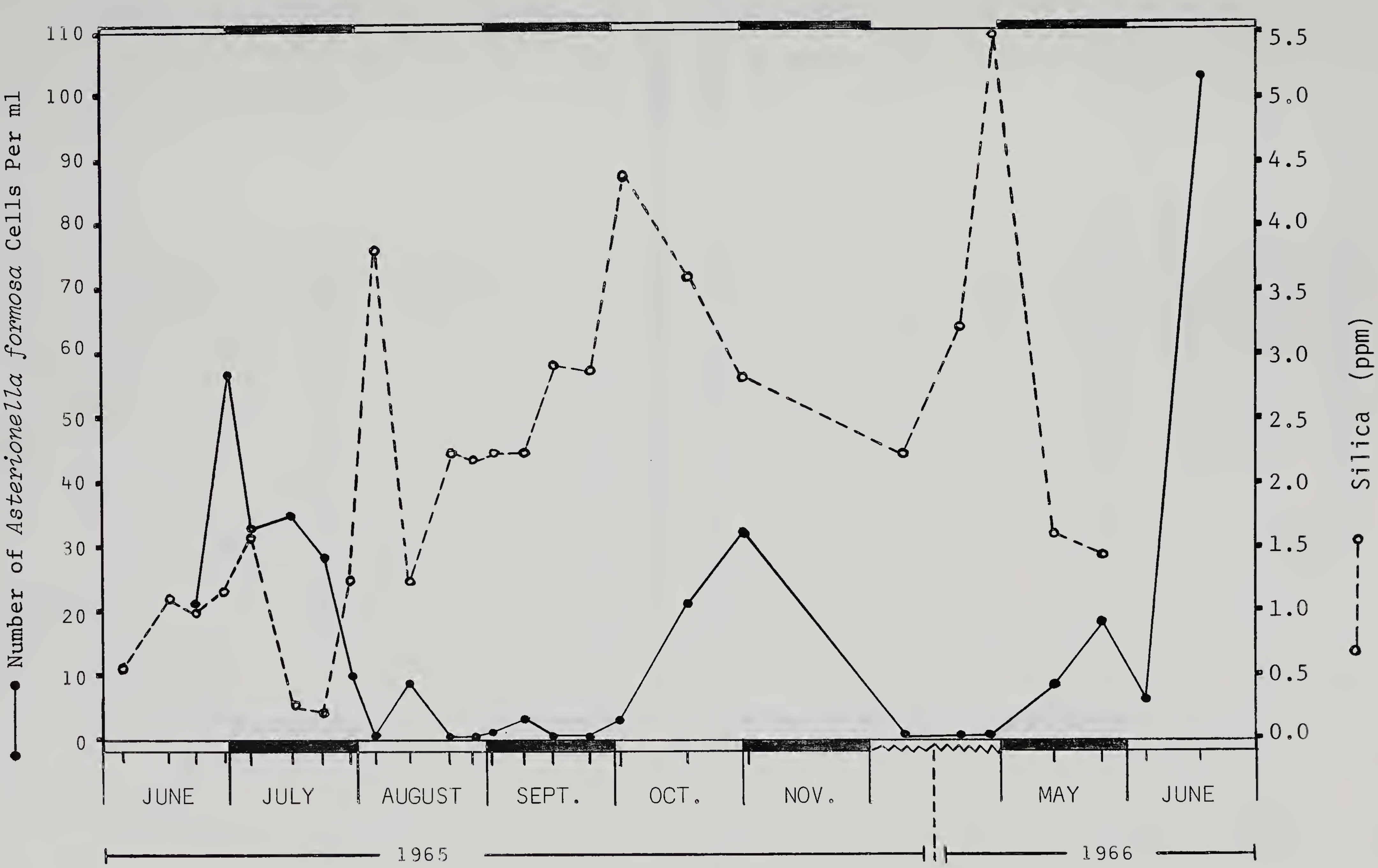
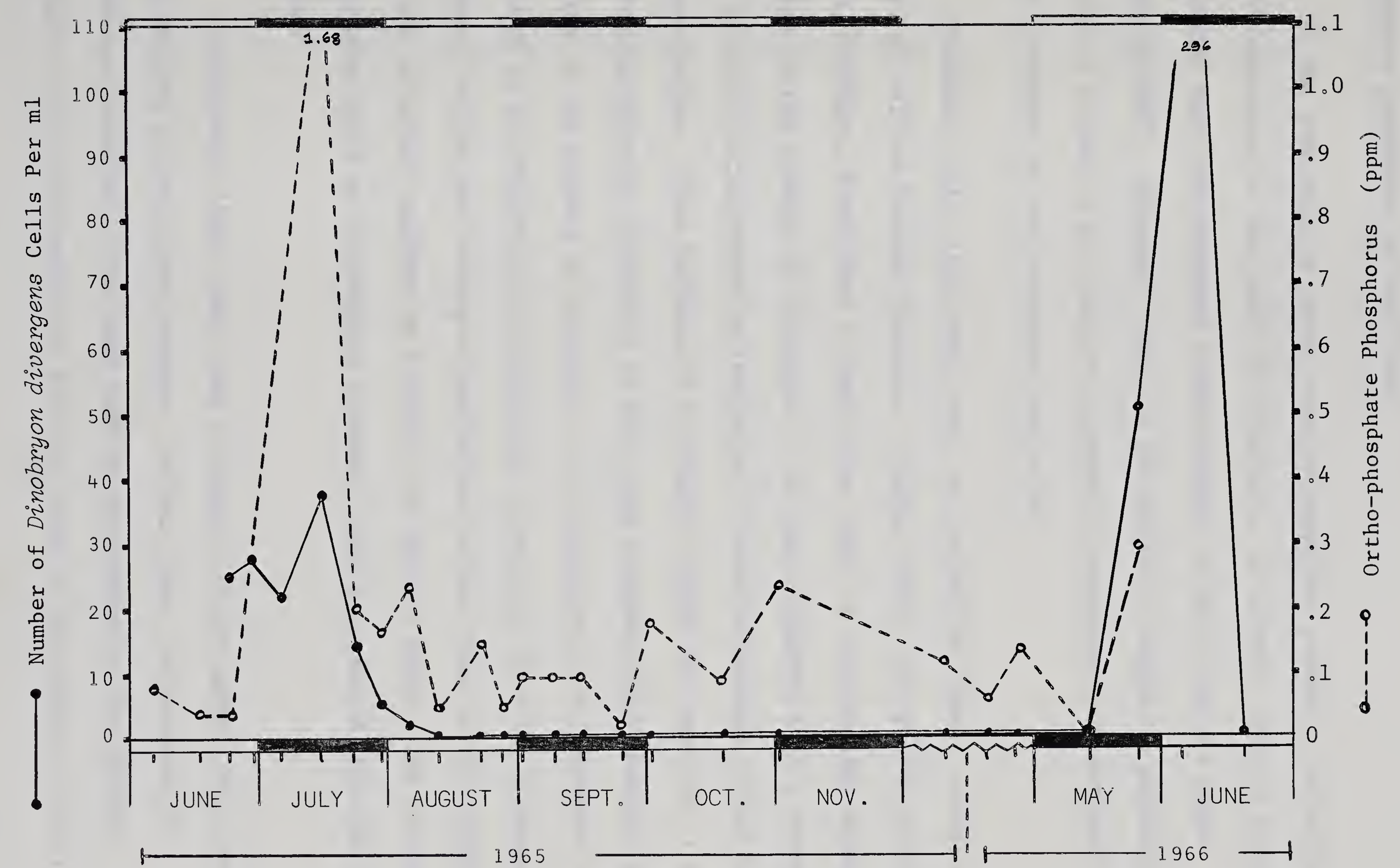

Number of *Asterionella formosa* Cells Per ml
Silica (ppm)
110
100
90
80
70
60
50
40
30
20
10
0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
JUNE
JULY
AUGUST
SEPT.
OCT.
NOV.
MAY
JUNE
1965
1966

Figure 39. Variations in the number of cells of *Dinobryon divergens* and the concentration of surface ortho-phosphate phosphorus in Muir Lake.



Number of Dinobryon divergens Cells Per ml
Ortho-phosphate Phosphorus (ppm)
110
100
90
80
70
60
50
40
30
20
10
0
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1.68
296
JUNE
JULY
AUGUST
SEPT.
OCT.
NOV.
MAY
JUNE
1965
1966

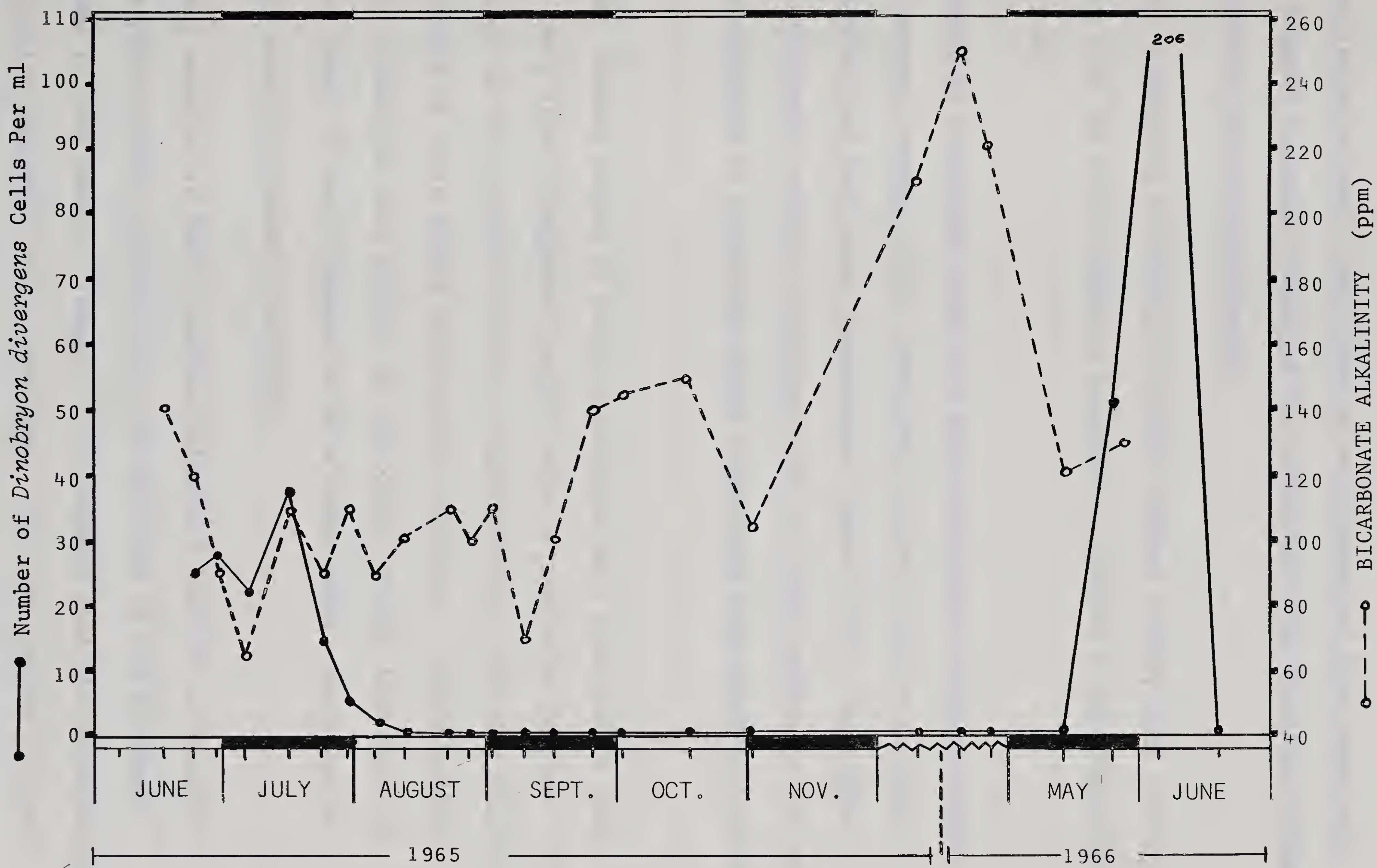
phosphate phosphorus in Muir Lake.

If the view held by Rodhe, that superoptimal phosphate concentrations are deleterious to the growth of *Dinobryon*, is correct, then it must be concluded that the phosphate concentrations in Muir Lake are below "superoptimum". Moreover, they are low enough to support a population of *Dinobryon* in such a way that an increase in phosphate is associated with increases in the *Dinobryon* population.

Pearsall (1932) also found that, in the English lakes, a drop in the level of calcium favored *Dinobryon*. Tucker (1957), who worked on Douglas Lake, Michigan, found that a rise in the level of bicarbonates accompanied a rise in the numbers of *Dinobryon* . He also suggested that a change in the level of bicarbonates is indicative of similar changes in the calcium concentration. From the data of my study, (Figure 40, page 186,) a rise in the bicarbonate alkalinity of Muir Lake occurred simultaneously with a rise in the numbers of *Dinobryon*. If variations in bicarbonates can be used as an indication of variations in calcium, then the relationship between calcium and *Dinobryon* populations in Muir Lake is the reverse of the situation reported by Pearsall for English lakes. The relationship here would be in complete agreement with the results obtained by Tucker.

Hutchinson (1944) found that *Dinobryon* did not appear until after the decline of the diatom maximum. In Muir Lake, the maximum of *Dinobryon* occurred at the same time as the maximum of the diatom *Synedra ulna* in the spring of 1965 and again in the spring of 1966.

Figure 40. Variations in the number of cells of *Dinobryon divergens* and the concentration of bicarbonate alkalinity in Muir Lake.


Number of Dinobryon divergens Cells Per ml
BICARBONATE ALKALINITY (ppm)
110
100
90
80
70
60
50
40
30
20
10
0
260
240
220
200
180
160
140
120
100
80
60
40
206
JUNE
JULY
AUGUST
SEPT.
OCT.
NOV.
MAY
JUNE
1965
1966

The occurrence of *Dinobryon* in Muir Lake may also be related to the physical factor of wind. Muir Lake is well protected from winds and is not exposed to severe mixing of the waters with the resulting release of phosphorus from the hypolimnion.

The Chrysophyte *Mallomonas acaroides* reached a sharp peak on July 28 at which time the total phosphate phosphorus attained a high concentration of 2.1 ppm.

Pulses of blue-green algae have been correlated with high organic matter content (Pearsall 1932, Vance 1965), high T.D.S. or salinity (Hammer 1964) and high water temperatures (Leake 1945). The higher T.D.S. and organic matter in Hastings Lake is likely reponsible for the greater abundance of blue-green algae in Hastings Lake compared with Muir Lake.

Few dormant stages of the phytoplankton were found during this study. Many algae disappeared rapidly after a population decline. Colonial algae such as *Uroglenopsis americana* dissociated into isolated cells or small groups of cells during unfavorable conditions. *Stephanodiscus astraea* in Hastings Lake settled to the bottom in very late fall and remained there, in what appeared to be a viable state, until spring turnover when they became resuspended.

Many examples in the literature point to a lack of correlation between phytoplankton periodicities and the level of the different nutrients in lake waters. Tucker (1957) suggests that the phytoplankton might utilize suspended ferric complexes. Thus the picture of algal periodicities as correlated with nutrient fluctuations in natural waters,

is incomplete, since investigations have normally employed techniques for the detection of soluble compounds. The concentration of a certain nutrient in the water is an indication of supply, but an indication of consumption may be equally important in determining the effect of a nutrient, or its limitations, on the growth of the phytoplankton. Gerloff and Skoog (1954) have suggested that the content of nitrogen and phosphorus in the cells of algae may be a good measure of the availability of these nutrients in natural waters. Fogg (1965) showed that division of algal cells can continue if the nitrogen supply is withdrawn until a certain limiting concentration of this element in the cells is reached. Rodhe (1948) showed that if the iron is removed from the solution of a highly productive culture of *Scenedesmus quadricauda* and the iron-free medium repeatedly renewed, the cells continue their growth and chlorophyll production for half a year before stopping. Similarly,with phosphorus, there may be a "luxury consumption" (Fogg 1965) of this element when the supply is ample, resulting in a reserve within the cells which can be drawn upon to maintain growth when the supply in the water is exhausted. as shown for *Asterionella formosa* by Lund (1950). It becomes obvious that, as a rule, direct correlations between phytoplankton cycles or pulses and nutrient fluctuations cannot be expected.

Many investigators have employed the results of laboratory cultures of lake waters to establish a complete floristic record of the phytoplankton in the lake. By the culturing of water samples it is hoped that dormant stages will develop into more characteristic forms. Although such data is useful, caution should be employed when drawing conclusions as to the importance and role in nature of the algae which become dominant in culture.

Culturing of ice-water revealed many viable algae in both of the lakes studied during this investigation. Similarly, cultures of lake water from beneath the ice cover resulted in the growth of many green algae which were not detected at the time of sampling. It appears likely that many species of phytoplankton are able to carry out heterotrophic metabolism beneath the cover of ice and snow and utilize organic matter (Rodhe 1955, Prowse 1955). Some algae are able to carry on an heterotrophic metabolism simultaneously with photosynthesis in the presence of light (Rodhe 1955). ZoBell (see discussion following Rodhe 1955) proposes that the " μ-algae" are able to carry on an autotrophic metabolism in the absence of light under the ice by oxidizing molecular hydrogen. Hydrogen is oxidized by certain photosynthetic bacteria, and it is not beyond the realm of possibility that hydrogen is available in lakes from anaerobic decomposition of organic matter. If these various modes of nutrition are in operation in winter, it may well be that, with present techniques, it is impossible to detect the minute and likely colorless algae. Winter data will be a necessary supplement to the voluminous summer data now available if the aquisition of basic information on lake biology is to be obtained.

Phytoplankton studies have tended to be concentrated on fluctuations of total populations which, while they are of great interest biologically, may not be of the same importance as far as practical fish farming is concerned (Prowse 1955). If the phycologist is to be of the maximum value to the fish farmer and at the same time continue to conduct theoretical research, he must focus his attention on individual components of the phytoplankton community rather than the community as

a whole. If production is to be increased, we must find out which components of the phytoplankton are beneficial to the rest of the food chain and learn about their ecology. In order to study the ecology of these phytoplankton components of the community, it is necessary to do so both in the field and in the laboratory. Many difficulties encountered by experimenters on algae in the laboratory have been caused by a lack of knowledge of the normal periodicity of these algae in nature. In the future, more harmonious work between field and laboratory disciplines will be a prerequisite to the solutions of the many problems arising from a study of the ecology of algae.

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A P P E N D I C E S

APPENDIX A Physico-Chemical Data

TABLE A_1 - Muir Lake Physico-Chemical Data

TABLE A_2 - Hastings Lake Physico-Chemical Data

APPENDIX B Quantitative Phytoplankton Data

TABLE B_1 - Cell Counts (Number Per ml) Of Phytoplankton In Muir Lake Expressed As The Average At Each Station For Each Sampling Date

TABLE B_2 - Cell Counts (Number Per ml) Of Phytoplankton In Hastings Lake Expressed As The Average At Each Station For Each Sampling Date

TABLE B_3 - Total Number Of Phytoplankton Units (Per ml Of Sample) Of The Major Algal Groups From Station 1 At Muir Lake For Each Sampling Date With Monthly Means.

TABLE B_4 - Total Number Of Phytoplankton Units (Per ml Of Sample) Of The Major Algal Groups From Stations 1 And 2 At Hastings Lake For Each Sampling Date With Monthly Means

TABLE A_1

Muir Lake Physico-chemical Data

	STN.	DEPTH	JUNE 8	JUNE 15	JUNE 23	JUNE 30	JULY 7	JULY 14	JULY 21	JULY 28	AUGUST 4	AUGUST 11	AUGUST 18	AUGUST 25
WATER TEMPERATURE °C	2	S	-	-	18.0	17.0	19.0	21.0	19.7	-	24.5	23.5	19.0	19.0
		1M	-	-	17.0	16.0	19.0	19.2	19.7	-	24.2	23.5	19.0	19.0
		2M	-	-	-	-	-	17.8	19.7	-	23.5	23.0	18.7	18.5
		3M	-	-	16.8	15.5	-	16.6	18.6	-	23.0	22.0	18.0	18.5
		4M	-	-	16.0	15.0	15.0	16.0	17.5	-	21.0	21.3	18.0	18.3
TIME OF READING	2		-	-	1330	1400	1100	1330	1015	-	1500	1200	1100	1400
AIR TEMP (°C)	1		-	19.0	20.50	18.0	-	22.5	-	23.0	25.9	24.0	20.6	17.2
SECCHI DISC READINGS (cm)	1		-	-	168	191	232	284	281	275	266	244	150	140
	2		-	-	168	175	232	280	260	265	207	186	140	119
WATER LEVEL (cm)			*10.67	9.14	11.2	43.47	47.30	49.84	47.3	45.39	42.73	40.69	39.37	37.87
ICE THICKNESS (cm)	1													
	2													
SNOW COVER (cm)	1													
	2													

	STN.	DEPTH	SEPTEMBER 1	SEPTEMBER 8	SEPTEMBER 15	SEPTEMBER 25	OCTOBER 1	OCTOBER 17	NOV. 1	DEC. 20	FEB. 6	MAR. 14	MAY 12	MAY 26
WATER TEMPERATURE °C	2	S	-	14.6	10.9	9.0	-	-	5.8	0.5	-	-	-	-
		1M	-	14.6	10.9	8.6	-	-	5.5	0.5	-	-	-	-
		2M	-	14.6	10.9	8.6	-	-	5.5	1.8	-	-	-	-
		3M	-	14.2	10.9	8.8	-	-	5.5	2.5	-	-	-	-
		4M	-	14.0	10.9	9.0	-	-	5.6	3.8	-	-	-	-
TIME OF READING	2		-	1200	1500	1300	-	-	-	1330	-	-	1350	-
AIR TEMP (°C)	1		11.8	-	-	-0.2	9.6	-	11.9	0.5	-9.0	4.0	13.0	20.2
SECCHI DISC READINGS (cm)	1		106	160	190	180	185	-	165	270	266	305	120	171
	2		120	150	180	140	-	-	160	260	-	-	-	-
WATER LEVEL (cm)			39.68	38.41	34.6	37.14	35.87	33.07	31.81	-	-	-	39.74	35.82
ICE THICKNESS (cm)	1									26.7	48.3	66.03		
	2									28.0	-	-		
SNOW COVER (cm)	1									7.6	35.6	15.3		
	2									7.6	-	-		

* Readings All + From 0 Mark On May 12

TABLE A_2

Hastings Lake Physico-chemical Data

	STN.	DEPTH	JUNE			JULY					AUGUST			
			9	16	24	1	8	15	22	29	5	12	19	26
WATER TEMPERATURE °C	2	S	-	-	16.2	16.5	18.8	20.0	19.2	21.5	22.0	22.5	20.2	17.4
		1M	-	-	16.2	15.0	18.8	19.8	19.2	21.0	22.0	22.0	18.8	17.4
		2M	-	-	16.2	14.0	18.8	19.6	19.2	20.5	22.0	21.8	18.0	17.4
		3M	-	-	16.1	13.6	18.5	18.0	19.1	20.0	20.5	21.5	18.0	17.4
		4M	-	-	16.0	13.9	18.0	17.5	19.0	20.0	20.5	21.4	17.9	17.2
TIME OF READING	2		-	1500	1100	0830	1030	0900	1000	1000	1016	0939	0930	0945
AIR TEMP (°C)	2		-	-	21.0	19.0	20.5	-	-	21.5	23.2	23.6	22.0	12.6
SECCHI DISC READINGS (cm)	1		-	-	72.5	111	110	110	60	38	42	44	25.0	36.0
	2		-	-	72.5	84	81	80	58	48	38	31	*28.0	26.0
	3		-	-	72.5	110	110	-	-	60	49	44	25.0	39.0
WATER LEVEL (cm)			**7.3	5.4	5.08	48.53	54.58	56.08	54.98	53.24	49.9	46.1	43.56	41.33
ICE THICKNESS (cm)	1													
	2													
SNOW COVER (cm)	1													
	2													

	STN.	DEPTH	SEPTEMBER				OCTOBER			DEC.	FEB.	MAR.	MAY	
			2	9	16	24	2	16	30	18	5	13	11	25
WATER TEMPERATURE °C	2	S	13.8	13.8	9.0	9.5	8.8	7.7	6.7	1.7	0.6	0.6	12.7	13.6
		1M	13.8	13.8	9.0	9.3	8.4	7.7	6.7	1.7	0.8	1.2	12.7	12.9
		2M	13.8	13.8	9.0	9.1	8.4	7.7	6.7	1.7	1.6	2.2	12.7	12.7
		3M	13.8	13.8	9.0	9.0	8.3	7.7	6.7	-	3.0	3.5	12.7	12.4
		4M	14.0	13.0	9.2	9.1	8.7	7.7	6.9	2.2	3.2	3.8	12.5	12.4
TIME OF READING	2		1030	1100	1100	1315	1130	1200	1200	1145	1100	1130	1215	1100
AIR TEMP (°C)	2		12.2	8.0	4.6	9.5	-	8.7	8.7	-4.0	-8.0	0.6	-	18.0
SECCHI DISC READINGS (cm)	1		34	32	41	48	45	55	-	240	258	275	55	70
	2		21	26	28	36	31	43	-	260	240	178	34	63
	3		45	-	41	-	-	54	-	-	-	-	-	-
WATER LEVEL (cm)			44.7	42.28	40.38	39.36	37.34	33.28	33.02	-	-	-	35.34	30.74
ICE THICKNESS (cm)	1									30.0	58.4	71.12		
	2									40.6	55.9	58.4		
SNOW COVER (cm)	1									3.8	30.0	30.5		
	2									3.8	30.0	33.02		

* 52 cm at 4:00 PM

** Readings All + From Zero Mark On May 11

TABLE B_1

Cell Counts (Number Per ml) Of Phytoplankton In Muir Lake

Expressed As The Average At Each Station For Each Sampling Date

SPECIES	STATION	JUNE 8	JUNE 15	JUNE 23	JUNE 30	JULY 7	JULY 14	JULY 21	JULY 28	AUGUST 4	AUGUST 11	AUGUST 18	AUGUST 25	SEPTEMBER 1	SEPTEMBER 8	SEPTEMBER 15	SEPTEMBER 25	OCT. 1	OCT. 17	NOV. 1	DEC. 20	FEB. 6	MAR. 14	MAY 12	MAY 26	JUNE 6	JUNE 18
Scenedesmus dimorphus	1	-	-	27	9	10	7	0	33	10	33	11	4	10	19	60	62	156	29	41	13	20	0	62	99	23	0
	2	-	-	4	0	0	40	0	0	0	33	6	256	26	14	20	30	-	-	114	57	-	-	-	-	-	-
Scenedesmus quadricauda	1	-	-	43	45	13	39	13	81	6	151	16	103	42	18	81	239	272	70	45	88	0	66	80	161	161	23
	2	-	-	13	26	34	188	12	12	0	62	33	241	80	57	82	82	-	-	131	205	-	-	-	-	-	-
Scenedesmus bijuga	1	-	-	0	0	0	0	0	0	0	0	6	6	13	23	26	0	20	0	0	0	0	0	6	0	46	0
	2	-	-	0	0	0	0	0	0	0	0	17	0	24	40	23	12	-	-	0	0	-	-	-	-	-	-
Pediastrum boryanum	1	-	-	0	34	0	34	0	0	0	0	0	1	0	29	0	0	615	0	0	0	0	0	0	0	0	0
	2	-	-	0	0	34	34	0	0	0	0	0	0	0	0	293	0	-	-	0	0	-	-	-	-	-	-
Pediastrum duplex	1	-	-	17	0	0	68	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0	0
	2	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	0	-	-	-	-	-	-
Pediastrum obtusum	1	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	103	0
	2	-	-	-	0	0	0	0	0	0	0	0	13	0	0	0	13	-	-	0	0	-	-	-	-	-	-

TABLE B_1 Continued

SPECIES	STATION	JUNE 8	JUNE 15	JUNE 23	JUNE 30	JULY 7	JULY 14	JULY 21	JULY 28	AUGUST 4	AUGUST 11	AUGUST 18	AUGUST 25	SEPTEMBER 1	SEPTEMBER 8	SEPTEMBER 15	SEPTEMBER 25	OCT. 1	OCT. 17	NOV. 1	DEC. 20	FEB. 6	MAR. 14	MAY 12	MAY 26	JUNE 6	JUNE 18
Pediastrum tetras	1	-	-	0	0	0	0	0	0	0	0	0	3	6	78	0	6	0	0	0	0	0	0	0	16	0	0
	2	-	-	-	0	0	0	0	0	0	0	0	0	0	0	6	0	-	-	0	0	-	-	-	-	-	-
Ankistrodesmus falcatus	1	-	-	12	22	0	0	3	0	32	55	47	61	176	228	90	0	98	33	52	16	2	0	0	15	46	19
	2	-	-	4	15	0	12	0	0	0	23	0	60	202	114	139	60	-	-	34	24	-	-	-	-	-	-
Lagerheimia quadriseta	1	-	-	14	9	1	0	0	0	0	0	0	0	1	0	4	3	7	18	146	133	10	0	74	126	11	0
	2	-	-	6	8	0	0	1	0	0	0	0	0	0	0	4	4	-	-	175	123	-	-	-	-	-	-
Actinastrum hantzschii	1	-	-	0	4	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	0	-	-	-	-	-	-
Cosmarium punctulatum	1	-	-	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0
	2	-	-	0	0	0	3	4	0	0	0	0	0	0	0	0	0	-	-	0	0	-	-	-	-	-	-
Coelastrum microporum	1	-	-	100	418	0	0	50	0	0	0	0	33	0	0	0	0	0	0	0	0	0	0	0	76	0	0
	2	-	-	0	0	114	114	114	0	0	0	0	0	0	0	0	0	-	-	0	0	-	-	-	-	-	-
Staurastrum curvatum var. paradoxum	1	-	-	7	6	0	2	3	2	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	2	-	-	1	0	3	0	4	0	0	0	3	0	0	0	0	0	-	-	0	0	-	-	-	-	-	-

TABLE B_1 Continued

SPECIES	STATION	JUNE				JULY				AUGUST				SEPTEMBER				OCT.		NOV.	DEC.	FEB.	MAR.	MAY		JUNE	
		8	15	23	30	7	14	21	28	4	11	18	25	1	8	15	25	1	17	1	20	6	14	12	26	6	18
Cerasterias staurasteroides	1	-	-	0	0	0	0	0	0	0	0	0	8	4	2	1	2	2	1	0	0	0	0	0	0	6	0
	2	-	-	0	0	0	0	0	0	0	0	0	2	2	4	0	2	-	-	0	0	-	-	-	-	-	-
Pandorina morum	1	-	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	0	-	-	-	-	-	-
Tetraedron limneticum	1	-	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	2	0	0	0	0	-	-	0	0	-	-	-	-	-	-
Tetraedron trigonum	1	-	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	18	7	0	6	0
	2	-	-	0	0	0	0	0	0	0	0	0	3	0	2	0	2	-	-	0	0	-	-	-	-	-	-
Trachelomonas spp.	1	-	0	0	0	0	0	0	0	0	0	0	0	1	11	14	6	26	14	11	0	0	0	6	22	23	6
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	71	6	0	-	-	18	16	-	-	-	-	-	-
Chlamydomonas globosa	1	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2	40	2	1	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	60	-	-	-	-	-	-
Lepocinclis acuta	1	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	0	-	-	-	-	-	-

TABLE B_1 Continued

SPECIES	STATION	JUNE 8	JUNE 15	JUNE 23	JUNE 30	JULY 7	JULY 14	JULY 21	JULY 28	AUGUST 4	AUGUST 11	AUGUST 18	AUGUST 25
Euglena spp.	1	-	0	1	2	0	1	2	2	2	3	10	6
	2	-	-	1	0	0	0	5	0	19	0	6	4
Phacus nordstedtii	1	-	0	0	0	0	0	0	24	2	6	10	3
	2	-	-	0	0	0	0	0	0	0	0	2	12
Phacus acuminatus	1	-	0	0	0	0	0	0	0	0	0	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	3
Treubaria setigerum	1	-	0	0	0	0	0	0	0	0	0	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	0
Anabaena flos-aquae	1	-	-	2,693	1,308	342	171	456	423	553	106	195	716
	2	-	-	4,145	1,725	542	350	513	1,140	456	57	513	969
Anabaena circinalis	1	-	-	0	0	0	0	388	390	912	155	390	228
	2	-	-	0	0	0	0	96	684	798	157	171	171
Anabaena macrospora	1	-	-	0	0	0	0	0	0	0	350	994	1,771
	2	-	-	0	0	0	0	0	0	0	370	684	2,052

SPECIES	STATION	SEPTEMBER 1	SEPTEMBER 8	SEPTEMBER 15	SEPTEMBER 25	OCT. 1	OCT. 17	NOV. 1	DEC. 20	FEB. 6	MAR. 14	MAY 12	MAY 26	JUNE 6	JUNE 18
Euglena spp.	1	2	0	3	9	1	1	1	0	0	3	5	0	1	0
	2	0	17	0	0	-	-	0	0	-	-	-	-	-	-
Phacus nordstedtii	1	0	3	11	4	25	4	6	9	0	8	7	9	11	0
	2	2	4	0	0	-	-	6	0	-	-	-	-	-	-
Phacus acuminatus	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0
	2	2	2	0	0	-	-	0	0	-	-	-	-	-	-
Treubaria setigerum	1	0	0	0	0	0	0	0	0	0	0	2	10	0	0
	2	0	0	0	0	-	-	0	0	-	-	-	-	-	-
Anabaena flos-aquae	1	1,335	586	651	162	81	0	0	0	0	0	0	0	114	875
	2	1,082	740	513	57	-	-	0	0	-	-	-	-	-	-
Anabaena circinalis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	-	-	0	0	-	-	-	-	-	-
Anabaena macrospora	1	358	97	0	0	0	0	0	0	0	0	0	0	0	0
	2	339	0	0	0	-	-	0	0	-	-	-	-	-	-

TABLE B_1 Continued

SPECIES	STATION	JUNE				JULY				AUGUST				SEPTEMBER				OCT.		NOV.	DEC.	FEB.	MAR.	MAY		JUNE	
		8	15	23	30	7	14	21	28	4	11	18	25	1	8	15	25	1	17	1	20	6	14	12	26	6	18
Merismopedia tenuissima	1	-	-	80	89	0	12	13	416	91	79	2,267	6,579	144	26	65	12	794	0	0	0	0	0	0	15	0	0
	2	-	-	37	0	684	61	0	273	0	0	0	12	13	23	269	0	22	-	-	0	0	-	-	-	-	-
Ceratium hirundella	1	-	-	2	0	1	3	1	0	6	0	4	1	0	0	1	0	0	0	0	0	0	0	1	0	6	0
	2	-	-	1	0	0	2	2	0	0	2	0	2	2	0	0	0	-	-	0	0	-	-	-	-	-	-
Peridinium gatunense	1	-	-	0	1	0	2	2	0	1	3	1	1	8	0	0	1	2	2	0	0	0	0	8	3	17	6
	2	-	-	0	0	0	0	0	0	0	0	4	2	7	0	0	0	-	-	0	0	-	-	-	-	-	-
Mallomonas acaroides	1	-	-	0	19	4	24	65	1,363	225	51	1	1	6	4	12	4	1	2	0	0	0	0	4	8	6	0
	2	-	-	0	3	0	3	2	23	0	0	19	4	2	87	24	14	-	-	0	0	-	-	-	-	-	-
Asterionella formosa	1	-	-	21	57	33	35	28	10	0	9	0	0	3	7	0	0	3	21	32	0	0	0	8	29	6	103
	2	-	-	25	26	32	15	7	0	0	0	0	2	0	0	0	8	-	-	143	0	-	-	-	-	-	-
Synedra ulna	1	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	94	18	18	3	27	51	42	222	6
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	16	41	-	-	-	-	-	-
Dinobryon sertularia	1	-	-	554	61	87	48	24	6	0	35	0	0	0	10	25	13	4	0	2	0	0	0	133	1,991	1,226	0
	2	-	-	645	23	0	51	18	0	0	0	0	0	0	0	0	13	-	-	0	0	-	-	-	-	-	-

TABLE B_1 Continued

SPECIES	STATION	JUNE 8	JUNE 15	JUNE 23	JUNE 30	JULY 7	JULY 14	JULY 21	JULY 28	AUGUST 4	AUGUST 11	AUGUST 18	AUGUST 25	SEPTEMBER 1	SEPTEMBER 8	SEPTEMBER 15	SEPTEMBER 25	OCT. 1	OCT. 17	NOV. 1	DEC. 20	FEB. 6	MAR. 14	MAY 12	MAY 26	JUNE 6	JUNE 18
Dinobryon divergens	1	-	-	24	27	22	36	14	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51	96	0
	2	-	-	69	20	3	35	8	0	0	0	0	0	0	0	0	0	-	-	0	0	-	-	-	-	-	-
Cryptomonas erosa	1	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	6	2	99	0	0	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	53	16	-	-	-	-	-	-
Synura uvella	1	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	147	0	0	0	0	0	10	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	0	-	-	-	-	-	-
Uroglenopsis americana	1	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,300	0	0	0	0	0	0	76	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	0	-	-	-	-	-	-
Crucigenia tetrapedia	1	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	2	0	0	49	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	18	-	-	-	-	-	-
Oocystis parva	1	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	6	8	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	0	-	-	-	-	-	-

TABLE B_2

Cell Counts (Number Per ml) Of Phytoplankton In Hastings Lake
Expressed As The Average At Each Station For
Each Sampling Date

SPECIES	STATION	JUNE			JULY					AUGUST				SEPTEMBER				OCTOBER			DEC.	FEB.	MAR.	MAY		JUNE	
		9	16	24	1	8	15	22	29	5	12	19	26	2	9	16	24	2	16	30	18	5	13	11	25	6	18
Scenedesmus dimorphus	1	351	-	106	9	0	63	68	3	0	0	0	0	5	0	2	0	2	5	23	0	0	0	5	20	0	0
	2	-	-	9	9	0	119	0	5	5	5	142	0	242	0	11	114	69	68	162	30	0	200	91	234	0	0
	3	-	-	-	14	0	-	-	4	0	0	32	0	3	-	3	-	3	0	-	-	-	-	-	-	-	-
Scenedesmus quadricauda	1	452	-	73	62	83	156	69	7	23	2	7	2	5	2	5	2	2	7	23	25	0	1	5	76	51	46
	2	-	-	85	85	31	251	5	28	5	8	401	0	90	0	0	0	5	11	216	8	0	73	28	222	91	182
	3	-	-	-	97	76	-	-	0	0	3	71	97	3	-	0	-	35	0	-	-	-	-	-	-	-	-
Scenedesmus bernardii	1	15	-	0	2	2	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	-	-	12	12	0	54	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	-	-	-	0	58	-	-	0	0	0	0	0	0	-	0	-	0	0	-	-	-	-	-	-	-	-
Pediastrum boryanum	1	287	-	946	5,813	807	2,881	16,209	319	410	1,067	308	226	114	226	267	390	246	398	410	21	0	1,661	410	616	410	410
	2	-	-	275	10,927	359	1,751	205	41	41	154	41	615	410	307	513	872	873	920	1,333	0	0	4,101	0	461	410	1,641
	3	-	-	-	1,846	293	-	-	293	293	68	762	556	87	-	205	-	117	176	-	-	-	-	-	-	-	-
Pediastrum duplex	1	2,198	-	179	25	21	431	472	103	0	410	62	41	41	82	0	0	185	82	205	0	0	1,100	410	581	410	616
	2	-	-	-	2,565	0	103	51	0	0	103	51	0	205	51	359	103	205	410	103	0	0	2,104	770	1,390	616	3,078
	3	-	-	-	0	30	-	-	30	0	30	30	0	0	-	30	-	0	170	-	-	-	-	-	-	-	-

TABLE B_2 Continued

SPECIES	STATION	JUNE			JULY					AUGUST				SEPTEMBER				OCTOBER			DEC.	FEB.	MAR.	MAY		JUNE	
		9	16	24	1	8	15	22	29	5	12	19	26	2	9	16	24	2	16	30	18	5	13	11	25	6	18
Coelastrum microporum	1	535	-	1,862	1,053	1,158	1,573	296	0	0	23	23	0	0	0	0	68	23	91	0	0	0	91	46	228	910	4,788
	2	-	-	5,825	2,793	570	228	114	0	0	0	0	0	0	0	0	0	0	0	114	0	0	0	0	171	0	5,472
	3	-	-	-	648	182	-	-	0	0	0	32	0	65	-	32	-	32	32	-	-	-	-	-	-	-	-
Lagerheimia quadriseta	1	-	-	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	-	-	-	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	3	0	0
	3	-	-	-	1	1	-	-	0	0	0	0	0	0	-	0	-	0	0	-	-	-	-	-	-	-	-
Chlamydomonas globosa	1	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	82	27	130	81	0	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	16	208	14	0	0	0
	3	-	-	-	0	0	-	-	0	0	0	0	0	0	-	0	-	0	0	-	-	-	-	-	-	-	-
Oocystis parva	1	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	224	182	20	0	184	174	695	433	205
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	137	388	0	0	627	245	393	374	296
	3	-	-	-	0	0	-	-	0	0	0	0	0	0	-	0	-	0	124	-	-	-	-	-	-	-	-
Ankistrodesmus falcatus	1	-	-	0	0	0	0	0	0	0	0	5	0	0	1	0	0	9	0	0	0	2	6	5	0	0	0
	2	-	-	0	12	0	0	0	0	0	0	114	0	0	0	0	0	0	0	0	2	13	6	2	12	0	0
	3	-	-	-	0	0	-	-	0	0	0	0	0	0	-	0	-	0	0	-	-	-	-	-	-	-	-
Actinastrum hantzschii	1	315	-	35	14	50	51	37	23	5	9	5	0	5	0	33	37	201	766	91	0	0	0	45	80	0	0
	2	-	-	-	71	23	23	0	0	0	0	0	0	0	0	0	0	171	581	387	0	0	0	61	307	0	138
	3	-	-	-	6	137	-	-	12	0	6	6	0	6	-	49	-	143	417	-	-	-	-	-	-	-	-

TABLE B_2 Continued

SPECIES	STATION	JUNE			JULY					AUGUST				SEPTEMBER				OCTOBER			DEC.	FEB.	MAR.	MAY		JUNE	
		9	16	24	1	8	15	22	29	5	12	19	26	2	9	16	24	2	16	30	18	5	13	11	25	6	18
Closterium acutum	1	-	-	-	0	0	0	1	0	0	0	0	1	1	2	20	20	31	106	6	0	0	0	0	16	6	0
	2	-	-	-	2	0	0	0	0	0	0	0	2	1	15	13	13	17	18	3	0	0	0	0	10	6	6
	3	-	-	-	0	0	-	-	0	0	0	0	2	1	-	13	-	21	53	-	-	-	-	-	-	-	-
Staurastrum curvatus var. paradoxum	1	0	-	4	1	3	9	17	4	1	2	3	2	2	6	8	9	12	16	29	2	0	46	4	21	17	23
	2	-	-	-	2	2	9	7	6	0	0	21	4	2	2	11	6	7	18	49	0	0	420	2	2	11	40
	3	-	-	-	0	0	-	-	1	0	2	1	10	3	-	6	-	5	9	-	-	-	-	-	-	-	-
Cosmarium punctulatum	1	0	-	8	1	5	8	5	4	2	4	7	4	10	6	5	45	19	20	0	0	0	0	4	1	0	17
	2	-	-	-	2	6	0	0	4	4	4	2	7	4	6	0	32	118	12	0	0	0	0	0	3	0	17
	3	-	-	-	1	1	-	-	4	3	2	23	5	3	-	20	-	8	0	-	-	-	-	-	-	-	-
Pandorina morum	1	0	-	0	9	18	173	301	55	91	82	128	82	27	201	146	292	511	465	365	0	0	0	0	23	0	0
	2	-	-	0	2	32	205	205	136	68	45	0	114	45	228	91	91	112	222	1,322	0	0	0	0	0	0	0
	3	-	-	-	0	13	-	-	131	65	299	52	78	195	-	104	-	195	78	-	-	-	-	-	-	-	-
Schroederia judayi	1	0	-	0	10	5	6	1	0	0	1	1	0	1	0	2	1	3	14	68	14	0	45	5	11	0	23
	2	-	-	0	10	4	0	0	0	0	0	0	0	0	0	0	2	2	8	9	2	0	0	5	6	7	11
	3	-	-	-	6	2	-	-	1	1	0	1	0	1	-	0	2	4	6	-	-	-	-	-	-	-	-
Selenastrum gracilis	1	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	228	570	16	0	0	114	15	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	114	7	0	0	285	285	0	0
	3	-	-	-	0	0	-	-	0	0	0	0	0	0	-	0	-	0	34	-	-	-	-	-	-	-	-

TABLE B_2 Continued

SPECIES	STATION	JUNE			JULY					AUGUST				SEPTEMBER				OCTOBER			DEC.	FEB.	MAR.	MAY		JUNE	
		2	16	24	1	8	15	22	29	5	12	19	26	2	9	16	24	2	16	30	18	5	13	11	25	6	18
Phacus acuminatus	1	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	7	5	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	5	0	0
	3	-	-	-	0	0	-	-	0	0	0	0	0	0	-	0	-	0	0	-	-	-	-	-	-	-	-
Cryptomonas erosa	1	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
	3	-	-	-	0	0	-	-	0	0	0	0	0	0	-	0	-	0	0	-	-	-	-	-	-	-	-
Ceratium hirundella	1	0	-	1	2	1	13	21	72	31	43	53	15	21	12	5	5	1	0	0	0	0	0	0	1	0	51
	2	-	-	0	10	5	12	20	34	21	174	85	72	13	6	0	18	0	0	0	0	0	0	0	0	0	17
	3	-	-	0	1	2	-	-	4	75	153	48	14	4	-	3	-	5	0	-	-	-	-	-	-	-	-
Mallomonas acaroides	1	0	-	1	2	5	5	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	-	-	0	3	5	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	-	-	-	7	3	-	-	1	0	1	0	1	0	-	0	-	0	-	-	-	-	-	-	-	-	-
Tabellaria fenestrara var. asterionelloides	1	391	-	491	110	65	117	54	14	86	3	0	0	0	45	0	0	0	0	0	0	0	0	0	0	0	0
	2	-	-	0	0	11	34	51	66	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	-	-	-	131	3	-	-	3	1	0	65	8	7	-	0	-	0	0	-	-	-	-	-	-	0	0
Stephanodiscus astraea	1	76	-	197	187	461	971	758	594	146	479	636	764	735	644	789	475	529	541	314	57	1	150	154	218	17	63
	2	-	-	17	41	24	202	70	107	15	97	188	314	466	573	424	439	253	235	375	80	0	1,200	30	55	6	40
	3	-	-	-	342	75	-	-	273	24	180	783	712	699	-	836	-	481	367	-	-	-	-	-	-	-	-

TABLE B_2 Continued

SPECIES	STATION	JUNE 2	JUNE 16	JUNE 24	JULY 1	JULY 8	JULY 15	JULY 22	JULY 29	AUGUST 5	AUGUST 12	AUGUST 19	AUGUST 26
Tribonema minus	1	0	-	0	0	0	0	0	0	0	60	419	644
	2	-	-	0	0	0	0	0	0	159	9,534	8,379	18,083
	3	-	-	-	0	0	-	-	0	0	244	598	721
Anabaena flos-aquae	1	58	-	1,117	2,679	541	6,293	23,060	25,555	6,931	3,808	44,457	2,280
	2	-	-	2,037	2,039	5,180	4,161	27,759	7,638	14,307	22,456	19.323	2,393
	3	-	-	-	171	2,974	-	-	8.142	10,368	9,152	13,163	2,638
Anabaena circinalis	1	0	-	0	0	0	0	0	0	160	342	182	0
	2	-	-	0	0	0	0	0	0	228	57	0	0
	3	-	-	-	0	0	-	-	0	52	410	97	0
Merismopedia glauca	1	424	-	131	1,313	950	976	210	0	18	63	0	0
	2	-	-	825	1,886	182	273	46	0	23	0	0	0
	3	-	-	-	612	677	-	-	0	0	0	0	0
Coelosphaerium naegelianum	1	0	-	0	0	0	0	0	0	0	1,386	510	146
	2	-	-	0	0	0	0	0	0	0	1,641	1,641	4,925
	3	-	-	-	0	0	-	-	0	0	834	938	521
Chroococcus limneticus	1	0	-	0	0	0	0	0	0	0	0	0	0
	2	-	-	0	0	0	0	0	0	0	0	0	11
	3	-	-	-	0	0	-	-	0	0	0	0	0

SPECIES	STATION	SEPTEMBER 2	SEPTEMBER 9	SEPTEMBER 16	SEPTEMBER 24	OCTOBER 2	OCTOBER 16	OCTOBER 30	DEC. 18	FEB. 5	MAR. 13	MAY 11	MAY 25	JUNE 6	JUNE 18
Tribonema minus	1	463	385	453	240	77	188	0	0	0	0	0	0	0	0
	2	22,593	25,628	17,271	11,457	4,957	1,838	11,393	0	0	285	0	213	0	103
	3	672	-	342	-	61	0	-	-	-	-	-	-	-	-
Anabaena flos-aquae	1	197	69	46	23	34	0	0	0	0	0	0	44	0	0
	2	299	9	57	30	0	0	0	0	0	0	0	0	0	1,853
	3	228	-	30	-	30	0	-	-	-	-	-	-	-	-
Anabaena circinalis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	-	0	-	0	0	-	-	-	-	-	-	-	-
Merismopedia glauca	1	0	0	0	0	0	0	0	0	0	0	0	45	0	182
	2	0	0	0	0	0	0	0	0	0	0	0	45	0	1,094
	3	0	-	0	-	0	0	-	-	-	-	-	-	-	-
Coelosphaerium naegelianum	1	1,022	1,460	2,262	876	73	146	0	0	0	0	73	92	0	730
	2	3,233	3,283	2,918	547	182	547	182	0	0	0	182	182	0	0
	3	1,250	-	1,876	-	103	103	-	-	-	-	-	-	-	-
Chroococcus limneticus	1	1	0	1	7	10	15	0	0	0	0	11	17	155	257
	2	116	0	38	11	39	25	110	0	0	0	0	90	103	103
	3	0	-	7	-	0	7	-	-	-	-	-	-	-	-

TABLE B_3

Total Number Of Phytoplankton Units (Per ml Of Sample)
Of The Major Algal Groups From Station 1 At Muir Lake
For Each Sampling Date With Monthly Means

	JUNE		JULY				AUGUST				SEPT.				OCT.		NOV.	DEC.	FEB.	MAR.	MAY		JUNE
GROUP TOTALS	23	30	7	14	21	28	4	11	18	25	1	8	15	25	1	17	1	20	6	14	12	26	6
CHLOROPHYTA	43	43	7	17	7	29	9	54	16	48	49	65	59	83	153	48	174	180	18	66	127	225	101
EUGLENOPHYTA	1	2	0	1	2	26	4	9	20	9	5	14	28	20	52	19	18	9	0	11	28	31	35
CYANOPHYTA	72	38	8	5	20	63	41	19	177	931	50	18	20	5	51	0	0	0	0	0	0	1	2
PYRROPHYTA	2	1	1	5	3	0	7	3	5	2	8	0	1	1	2	2	26	6	2	99	9	3	23
CHRYSOPHYCEAE	578	107	113	108	103	1371	226	86	1	1	6	14	37	17	5	11	8	0	0	0	137	2050	1539
DIATOMEAE	21	57	33	35	28	10	0	9	0	0	1	2	0	0	3	115	50	18	3	27	59	451	228
GRAND TOTALS	717	248	162	171	163	1499	287	180	219	991	119	113	145	126	266	195	276	213	23	203	360	2761	1928
MONTHLY MEANS																							
CHLOROPHYTA	23		15				32				64				101		174	180	18	66	176		101
EUGLENOPHYTA	1.5		7				10.5				16				36		18	9	0	11	30		35
CYANOPHYTA	55		21				292				23				17		0	0	0	0	.5		2
PYRROPHYTA	1.5		2				4				3				2		26	6	2	99	6		23
CHRYSOPHYCEAE	343		423				78				19				8		8	0	0	0	1093		1539
DIATOMEAE	39		27				2.5				1				59		50	18	3	27	205		228
TOTALS	408		495				419				126				223		276	213	23	203	1510		1928

TABLE B_4

Total Number Of Phytoplankton Units (Per ml Of Sample) Of The Major Algal Groups From Stations 1 and 2 At Hastings Lake For Each Sampling Date With Monthly Means

GROUP TOTALS	STN.	JUNE 9	JUNE 16	JUNE 24	JULY 1	JULY 8	JULY 15	JULY 22	JULY 29	AUGUST 5	AUGUST 12	AUGUST 19	AUGUST 26	SEPTEMBER 2	SEPTEMBER 9	SEPTEMBER 16	SEPTEMBER 24	OCTOBER 2	OCTOBER 16	OCTOBER 30	DEC. 18	FEB. 5	MAR. 13	MAY 11	MAY 25	JUNE 6
CHLOROPHYTA	1	306	-	137	223	92	218	548	29	28	57	34	21	24	38	56	109	128	327	238	111	27	123	177	296	201
	2	-	-	194	497	47	186	32	29	11	17	176	37	114	48	57	115	210	197	457	52	18	550	162	342	170
EUGLENOPHYTA	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	5	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	5	0
CYANOPHYTA	1	28	-	36	148	72	218	589	634	178	119	1119	58	13	20	18	9	3	3	1	0	0	0	2	7	17
	2	-	-	101	167	140	121	696	190	364	575	496	99	45	22	22	6	5	7	12	0	0	0	1	14	12
PYRROPHYTA	1	0	-	1	2	1	13	21	72	31	43	53	15	21	12	5	5	1	0	0	0	1	0	0	1	0
	2	-	-	0	10	5	12	20	34	21	174	84	72	13	6	0	18	0	0	0	0	2	0	0	0	0
CHRYSOPHYCEAE	1	0	-	1	2	5	5	0	1	0	4	29	43	32	25	13	15	5	1	0	0	0	0	0	0	0
	2	-	-	0	3	5	8	5	0	11	636	559	1206	1506	1708	1151	764	330	122	63	0	0	0	0	14	0
DIATOMEAE	1	124	-	258	201	469	986	765	596	157	479	636	764	735	650	789	475	509	541	314	57	1	150	154	218	17
	2	-	-	17	41	25	206	76	115	15	97	188	314	466	573	424	439	253	235	375	80	0	800	30	55	6
GRAND TOTALS	1	458	0	433	576	639	1440	1923	1336	394	702	1871	901	825	745	881	613	646	872	553	168	29	274	340	527	235
	2	-	0	312	718	222	533	829	368	422	1045	1504	1728	2144	2357	1654	1342	798	561	907	132	20	1350	200	430	188

MONTHLY MEANS

MONTHLY MEANS	STN.	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	DEC.	FEB.	MAR.	MAY	JUNE
CHLOROPHYTA	1	222	222	35	57	231	111	27	123	237	201
	2	194	158	60	84	288	52	18	550	252	170
EUGLENOPHYTA	1	0	0	0	0	0	0	0	1	3.5	5
	2	0	0	0	0	0	0	0	0	3.5	5
CYANOPHYTA	1	32	333	368	15	2.5	0	0	0	4.5	17
	2	101	262	383	28	8	0	0	0	7.5	12
PYRROPHYTA	1	.5	22	36	11	.5	0	1	0	.5	0
	2	0	16	88	10	0	0	2	0	0	0
CHRYSOPHYCEAE	1	.5	3	19	21	2	0	0	0	0	0
	2	0	4	603	1,282	171	0	0	0	7	0
DIATOMEAE	1	191	603	509	662	454	57	1	150	186	17
	2	17	92	153	475	287	80	0	200	43	6
TOTALS	1	446	1183	967	766	690	168	29	274	432	240
	2	312	532	1327	1,879	754	132	20	1,350	200	188